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CONTINUING PROJECT **YEAR 3/3**

Title: Nitrogen Nutrition of Pears Grown Under Differing Soil and Environmental Conditions

Project leader: Timothy L. Righetti, Dept. of Horticulture, Oregon State University

Cooperators: Clark Seavert, Mid-Columbia Agriculture Research and Extension Center, Anita Azarenko, Dept. of Horticulture, Oregon State University.

Funding History: Final year, three-year study, 1st yr $28,800: 2nd yr $15,000
Current Request; $15,000

Justification:

Many of us believe that as we strive to become more efficient, fertility programs will become more complex. We need to know how important the tree storage, non-fertilizer soil sources, and fertilizer N pools are for pears grown under different conditions. The most appropriate strategy for an orchard in a clayey soil in Wenatchee may be quite different than what we want to do in a loam soil at Hood River. We believe that management strategies can be designed to meet the economic and environmental demands that face our industry, but there is not a one-size-fits-all solution.

A first step in the pursuit of developing management approaches for different soil and environmental conditions, is determining how much variability we are dealing with. We proposed to evaluate fertilizer efficiency, and the relative importance of tree storage, non-fertilizer soil sources, and fertilizer N pools at multiple Northwest locations under different soil environments. Trials are ongoing at Hood River and Medford, Oregon. These experiments are being conducted supplemented with non-WTFRC funds and the goals have been expanded to include assessments on the role of N in vigor control using both remote and ground based vigor assessments.

Specific hypotheses are listed below.

1) The ^{15}N estimates of fertilizer recovery may overestimate the real efficiency of plant uptake especially in high-organic matter systems.

2) Some pear growing systems can be defined as N saturated (more N available from fertilizer and soil mineralization than plants require). Under these conditions, increasing the efficiency of fertilizer or reserve utilization may decrease the use of N mineralized from the soil. Even though plants respond to N, we have more than we need.

3) The source of the N that can potentially contaminate groundwater varies for different pear growing systems and climates.

4) Mineralized N that is released from soil organic matter may be less efficiently used than fertilizer N, and the use of mineralized N will vary with pear variety and soil or environmental conditions.

Objectives:

1. Determine the relative importance of tree storage, soil and fertilizer N pools in meeting the nitrogen needs for pears grown under different soil and environmental conditions.

2. Determine uptake efficiency for pears grown under different soil and environmental conditions.

3. Investigate how soil texture, site-specific weather conditions, and soil organic matter may modify the uptake storage and utilization of fertilizer applied N at different locations.

4. Develop possible management strategies that incorporate soil and environmental factors into N fertilizer recommendations.

Activities and Accomplishments:

In order to evaluate all three sources of N (soil organic matter, fertilizer, tree reserves) in a given year, we need to have a set of labeled trees. Therefore this process takes a minimum of two years. After their initial ^{15}N treatment, all treated trees are fertilized with unlabeled N in the second year. A different set of trees is fertilized with labeled N in the second year. Dormant trees from both treatments are destructively sampled 2 years after the first exposure to ^{15}N. Evaluation of the second year data is ongoing at this time.

The percentage of N from the fertilizer can be determined by analyzing new growth for ^{15}N in trees that received labeled N during the current season. The rate that the label disappears in trees that were labeled in the previous season can be used to estimate the importance of the reserves. When we know how much N came from reserves and fertilizer we can estimate the importance of the soil source by subtraction.

It was possible to obtain some information on fertilizer N use in the first year. This data is similar to numerous other reports that we have made in the past. Although we will report on all currently available results during the research review, most of the important data will be produced this winter as we analyze data from excavated dormant trees excavated this year. Hopefully this second year information will be available at the pear research review. An evaluation of the third year data (proposed here) will give us two years of data with regard to the relative importance of tree storage, non-fertilizer soil sources, and fertilizer N pools at the Medford and Hood River locations.

Final Year Plans:

We will continue to evaluate the trials as described above. As part of a USDA funded project we will add more extensive assessments of tree vigor. More careful measurements of tree components will allow us to quantify the effects of N status on tree vigor. Since we will be destructively harvesting trees it will also provide us with an opportunity to look for relationships between remote assessments of tree vigor and the actual measurements of leaf biomass/structural biomass and 1-yr wood/total wood.

Budget: (Approximately 50% has been spent to date)

Analytical Services (~1200 samples @ $12.50)	15000.00
TOTAL	$15000.00

Project Changes

Originally we planed a 4-yr study. We will learn a great deal from the 3 years data that we will have. When we combine the data we have collected as part of this WTFRC sponsored project, with additional data that is being collected from research funded by non-WTFRC sources, we will have substantial publishable work. Although continued funding is possible I am afraid we may enter a time period of diminishing returns. Therefore we are planning to terminate the project one-year early.

CONTINUING PROJECT

Project title: Pear Rootstock and Regulated Deficit Irrigation Trial

PI: Tom Auvil
Organization: Washington Tree Fruit Research Commission

Cooperator: Randy Smith, Cashmere

Advisory Committee: Bob Gix, Blue Star
Randy Smith, Cashmere
Fred Valentine, Stemilt Growers, Inc.
Tim Smith, WSU Cooperative Extension
Chris Peters, WTFRC Commissioner

Background

This planting was established in 1996; the 2001 season is 6th leaf. Anjou are planted 14 x 8 with 389 trees per acre, the Bosc and Bartlett are planted 14 x 6 with 518 trees per acre. The rootstock trial evaluates the performance of the rootstocks OHxF 40 (not with Anjou) 69, 87, and 97 in a higher density planting with Anjou, Bartlett and Golden Russet Bosc in terms of yield, fruit size, maturity and quality. The regulated deficit irrigation trial was designed to determine if additional precocity can be gained through water management practices. Fruit and leaf nutrition is monitored to see if there is any difference in fruit quality between irrigation treatments.

2001 Procedures:

- ❖ Replacement of bearing surface through replacement of fruiting limbs was estimated at 8 to 10 years if the largest two limbs were removed per tree.
- ❖ The central leaders were well defined in the pruning program
- ❖ In addition to regular pruning program, Anjou on OHxF 87 was heavily detailed pruned and had 40 pounds of N/acre applied in the fall based on the judgement by the advisory committee that this rootstock/scion combination was beginning to stunt out and fruit size was too small. The other Anjou plots were not fertilized for the 2001.
- ❖ All Bartlett plots were fertilized twice to enhance fruit size at rate of 40# N/acre fall and 20# N/acre in the spring.

Results

- ❖ Harvested an average of 38 bins per acre (28 in 2000) across all varieties and rootstocks.
  - 36% increase in yield
- ❖ Peak sizes were 70's and 80's on all varieties. Fruit was more than 2 box sizes larger in 2001 than previous season across all varieties and treatments.

Significant Findings:

❖ Regulated Deficit Irrigation (RDI) did not impact fruit size on any variety. Yield efficiencies were statistically similar.

❖ Rootstock trends are particular to each variety. There is probably not a 'best' rootstock for all situations. There is one overall rootstock trait that OHxF 87 is starting to show more distinctly in 2001. This rootstock will grow a smaller tree as measured by trunk circumference. This would indicate that trees on OHxF 87 could be planted closer together than trees grown on the other rootstocks. It was fairly obvious last season that Anjou on OHxF 87 could be planted and maintained on a 14 x 6 spacing. It may well play out that on the less vigorous varieties that OHxF 87 could be planted at densities greater than 600 trees per acre.

- **Anjous**
  - OHxF 87 fruit size was comparable to other rootstocks this season due to adjustments in pruning and fertilization. The goal to improve OHxF 87 fruit size through cultural practices was achieved in 2001.
  - OHxF 69 did not improve its yield efficiencies as much as OHxF 97. OHxF 87 and 97 had statistically similar yield efficiency in 2001. In 2000, OHxF 87 had nearly double the efficiency of the other stocks. OHxF 87 is still the hands down winner in the production category due to its precocity with Anjou.
  - Even with the very detailed pruning the OHxF 87 still had high yield efficiency.
  - Vegetative growth was barely adequate in 2001. Maintaining vigor is still a concern with OHxF 87.
  - OHxF 87 may not be suitable for interplanting in existing blocks or on weak soils.
  - OHxF 87 may be particularly suited for use with vigorous, low precocity scions such as Anjou, Comice and Taylor's Gold.
- **Bosc**
  - Bosc are typically been a biennial bearer. This was not the case on any of the rootstocks this year in this trial
    - 2001 crop had similar fruit / tree counts as 2000
    - The fruit was 2.5 box sizes larger than in 2000, therefore yield per tree was up more than 25% on all rootstocks.
  - There were no statistical differences in fruit size due to rootstock effect. However the trend still holds that OHxF 87 can grow <u>smaller</u> fruit.
  - OHxF 69 and 87 are the most yield efficient rootstocks for Bosc in this trial. This trend is the same for both seasons.
  - OHxF 40 has the lowest yield on Bosc in 2000 and 2001.
- **Bartlett**
  - Fruit size was best on OHxF 40 and 69.
  - Yield efficiency was best on OHxF 87 and 40. The overall best performing rootstock with yield and fruit size for Bosc may be OHxF 40.
  - OHxF 97 was leaning to the small fruit size in 2000 and in 2001 did have significantly smaller fruit than the other rootstocks.

Rootstock effects

Bartlett	Pear#	Pounds	Lbs/Tree	Bin / A	Cmtv B/A[1]	BoxSize	TrunkCir	Kg/tcsa	Brix	Acid	Firm
40	2364a	1432a	90a	42a	78	73b	27.0a	.73a	12.2a	.38a	18.3b
69	2234ab	1305ab	82ab	38ab	72	76b	27.4a	.62b	12.1a	.38a	18.3b
87	2249a	1230b	77b	36b	65	77ab	24.3b	.74a	12.1a	.44a	18.8a
97	1982b	1140b	71b	34b	63	81a	26.4a	.58b	11.7a	.35a	18.7ab

Bosc	Pear#	Pounds	Lbs/Tree	Bin / A	Cmtv B/A[1]	BoxSize	TrunkCir	Kg/tcsa	Brix	Acid	Firm
40	2049a	1185c	74c	35c	63	75a	27.3a	.57b	12.2a	.13a	12.8a
69	2415a	1443a	90a	42a	76	74a	27.1a	.69a	12.8a	.14a	12.7a
87	2415a	1336ab	84ab	39ab	69	79a	26.4a	.68a	12.7a	.14a	12.6a
97	2188a	1284bc	80bc	38bc	68	74a	27.8a	.58b	12.6a	.14a	12.4a
Anjou	Pear#	Pounds	Lbs/Tree	Bin / A	Cmtv B/A[1]	BoxSize	TrunkCir	Kg/tcsa	Brix	Acid	Firm
69	3137b	1693b	106b	37b	60	82a	30b	.67b	13.3a	.34a	13.4ab
87	3657a	1880ab	117ab	42ab	90	86a	29.1b	.79a	13.6a	.28b	13.3b
97	3636a	1947a	122a	43a	68	82a	31.2a	.71ab	13.4a	.33a	13.8a

Irrigation Effects

Bartlett	Pear#	Pounds	Lbs/Tree	Bin / A	Cmtv B/A[1]	BoxSize	TrunkCir	Kg/tcsa	Brix	Acid	Firm
25	2219a	1286a	80a	38a	68	76a	25.7b	.69a	11.7b	.39a	18.6ab
50	2157a	1221a	76a	36a	66	78a	26ba	.65a	12.2a	.37a	18.7a
100	2245a	1355a	83a	39a	75	75a	27a	66a	12.1ab	.40a	18.3b

Bosc	Pear#	Pounds	Lbs/Tree	Bin / A	Cmtv B/A[1]	BoxSize	TrunkCir	Kg/tcsa	Brix	Acid	Firm
25	2093b	1220b	79b	36b	63	75a	26.8a	.60b	12.7a	.15a	12.8a
50	2573a	1452a	91a	43a	78	78a	27.5a	.68a	12.7a	.13b	12.6a
100	2133b	1265b	79b	37b	69	74a	27.2a	.61b	12.3a	.13b	12.6

Anjou	Pear#	Pounds	Lbs/Tree	Bin / A	Cmtv B/A[1]	BoxSize	TrunkCir	Kg/tcsa	Brix	Acid	Firm
25	3158b	1731a	108a	38a	70	80a	30.1a	.68a	13.5a	.33a	13.4a
50	3665a	1889a	118a	42a	71	86a	29.6a	.76a	13.7a	.31a	13.5a
100	3606a	1899a	119a	42a	77	83a	30.5a	.73a	13.1a	.31a	13.5a

[1] **Cumulative yield in Bins per Acre.**

Budget
Pear Rootstock and Regulated Deficit Irrigation Trial
Tom Auvil
Current year: 2002
Original budget request:

Total	11380	12,150	**16,600**

Current year breakdown

Item	2000	2001	**2002**
Salaries			
Benefits (%)			
Wages	6639	5740	**8,300**
Benefits (%)	1991	1910	**1,300**
Equipment	0	0	**0**
Supplies	150	1000	**2,000**
Fruit & leaf analysis	0	1000	**2500**
Fruit purchase	2500	2500	**2500**
Total	11380	12150	**16,600**

CONTINUING PROJECT **YEAR: Long-term**

TITLE: Evaluation of Pear Rootstocks

PROJECT SUMMARY: Eugene A. Mielke, OSU, MCAREC

COOPERATOR: Bill Proebsting, Horticulture Department

FUNDING HISTORY:
Year Initiated: Various
Funding in 2001-2002: $18,000

SIGNIFICANT FINDINGS:

No one rootstock will provide the optimum tree size, yield, fruit size, and quality for all cultivars or under all climatic, pathogenic, or insect regimes. Choices must be made based on location, soil condition, cultivar, and known insect and disease pressures. Generally trees on OHxF rootstocks have increased yields as compared to trees on seedling Bartlett roots. Winter Nellis seedling or Betulaefolia rootstocks appear to offer superior performance for Bartlett trees. No one OHxF rootstock is best for all cultivars. The use of interstems can reduce tree size, and increase fruit size, and productivity. The Horner rootstock series shows promise for producing rootstocks which offer some dwarfing characteristics while increasing yield and fruit size. Budding height affects canopy size and production. Too little is known about the budding height effect with different rootstocks and cultivars to even suggest a change in propagation practices at this time. Several new trials have been established as material has become available. These trials are one to three years old, and so far none of the rootstocks have been shown to be significantly superior.

OBJECTIVES:

To develop a rootstock that is precocious, produces large crops of high quality fruit, has some amount of dwarfing character in order to have orchards which can be efficiently managed from the ground or with short ladders and newer equipment that is more environmentally friendly, and ideally resistant (or at least tolerant) to the pests and diseases that plague Northwest growers.

1. Determine the optimum rootstocks for inducing dwarfing character, precocity, production, and fruit quality under varying soil and climatic conditions in the Northwest utilizing conventional rootstocks, interstems, and newly available rootstock material.
2. Determine the effect of budding height on productivity and size control.
3. Determine the decline sensitivity of the new rootstocks.

PROCEDURES:

Objective 1: Determine the optimum rootstocks for inducing dwarfing character, precocity, production, and fruit quality under varying soil and climatic conditions in the Northwest utilizing conventional rootstocks, interstems, and newly available rootstock material.

Maintain existing Bosc and Columbia Red d'Anjou plantings. Evaluate each plot annually for growth, flowering, productivity, and winter survival. Evaluate fruit for production, size, and quality. The following trials will be maintained:

a. 1993 Brossier interstems – terminate 2002
b. 1994 *Pyrus communis* interstems – terminate 2003
c. 1994 Bartlett trial – terminate 2003

d. 1996 Horner – terminate 2005
e. 1998/1999 Pyrodwarf, Fox and Retuzier – terminate 2007/2008
f. 2000 Pyrodwarf/Pyro II trial – terminate 2009
g. 2001 Fox/708 trial – terminate 2010
h. 2001 Pyronia trial – terminate 2010
i. Begin propagation of three Russian rootstocks for a 2005 trial – terminate 2014
j. Grossly evaluate the remainder of the Horner rootstock series. Three hundred of the Horner selections were propagated by cuttings in 2001, with the remainder to be propagated in 2002. These will be budded to d'Anjou and field planted in 2004 and 2005. Each set of selections would be evaluated for 5 years, and the superior selections identified for further development – Initial evaluation to terminate 2008-2009.

Objective 2. Determine the effect of budding height on productivity and size control.
Maintain existing d'Anjou planting budded at 3, 9, and 15 inches. Evaluate as above – terminate 2004.

Objective 3: Determine the fire blight sensitivity of the new rootstocks.
Rootstock liners of the new rootstocks and an OHxF control will be removed from the nursery row in a dormant state, potted, and transported to the USDA Germplasm Repository in Kerneysville, West Virginia where they will be evaluated for fireblight sensitivity.

RESULTS AND DISCUSSION:

1993 Interstems: The results of the 9-year d'Anjou and Bartlett trial with the South African (BP-1 and BP-2) and Brossier (PYR-2144 and PYR-2146) interstems on OHxF 97 roots continue to show some size reduction. Trees with BP-2 and PYR-2146 interstems continue to produce the greatest yields and are the most productive when adjusted for tree size. Fruit size was largest on trees with BP-1 interstems.

1994 Interstems: The results of the 8-year d'Anjou, Bartlett, Bosc, and Comice trial with *Pyrus communis* interstems on Bartlett seedling roots continue to show size control. Generally trees with Conference interstems were the shortest in height, had the narrowest canopy spread, and smallest canopy volumes. Significant interactions between cultivar and interstem occurred in accumulated production. While the actual accumulated yields generally showed little significant differences between the interstems within a cultivar, when the accumulated yields were adjusted for tree size, more significant differences were observed. This was particularly true for Comice.

1994 Bartlett: The results of a 8-year trial of Bartlett trees with two seedling and Betulaefolia rootstocks continues to show significantly larger tree size and production where Betulaefolia rootstocks are used. Fruit size was not related to yield, as the fruit size on trees with Betulaefolia and Winter Nellis roots continue to be significantly larger as compared to fruit size on trees with seedling Bartlett roots. When accumulated production was adjusted for tree size, Bartlett trees with Winter Nellis roots were the most productive.

1996 Horner: The results of the 1996 Horner rootstock trial with d'Anjou pears continue to show as the trees become older, the differences previously seen between the rootstocks have become smaller. D'Anjou trees with all the Horner selections have smaller canopy spreads with smaller canopy volumes than d'Anjou trees with OHxF 97 roots. Trees with H-4 and H-10 roots continue to have greater production than d'Anjou trees with OHxF 97 roots. D'Anjou trees with H-4 roots continue to

produce the largest sized fruit. Accumulated yield continues to be greater on d'Anjou trees with H-4 and H-10 roots.

1999 English 708 and OH11 Rootstock Trials: In the 3-year-old green d'Anjou, Bartlett, Golden Russet Bosc, and Comice trial with 708-2, 708-12, 708-36, OH11, and Bartlett seedling rootstocks, only trees with OH11 rootstocks were significantly smaller than the controls as measured by trunk cross sectional area. First and full bloom within a cultivar was affected by as much as two days; however, due to the variability in the young trees, none of the differences were statistically significant. None of the rootstocks significantly increased third-leaf flowering

2000 Pyrodwarf and Pyro II Rootstock Trial: In a 2-year-old Bartlett, Comice, and Concorde trial with Pyrodwarf, Pyro II, and OHxF 97 rootstocks, only Bartlett with Pyrodwarf rootstocks produced trees with a smaller TCSA than did the control (OHxF 97). Tree height was not affected by rootstock. While some differences were observed in the number of flower clusters, none of the differences were significant.

2001 English 708 and Fox Rootstock Trial: In a 1-year-old d'Anjou and Bartlett trial with 708-2, 708-12, 708-36, Fox 11, Fox 16, OHxF 40, and OHxF 87 rootstocks, none of the rootstocks produced trees with TCSAs that were significantly different from the controls.

2001 Pyronia and 708-36 Rootstock Trial: In a 1-year-old d'Anjou and Columbia Red d'Anjou trial with Pyronia (*P. pyronia sp.*), 708-36, OHxF 87, and OHxF 97 rootstocks, d'Anjou trees with Pyronia rootstocks were not significantly different in either TCSA or tree height than with the d'Anjou trees with OHxF 87 rootstocks. In the Columbia Red d'Anjou trial, trees with 708-36 rootstocks had significantly larger TCSAs and were taller than trees with the control OHxF 97 rootstocks.

Horner Mother Block Evaluation: Liners were produced by cutting from the first 300 of the remaining selections by Bill Proebsting. These will be shipped to Fowler Nursery in the spring to be grown out and have d'Anjou tops put on. Two trees of each selection will be planted in 2004 in a 5' x 5' x 16' double-row planting. These trees will be initially evaluated for 5 years for dwarfing character, precocity, productivity, and fruit size. The remaining 200+ selections will be propagated this year for a 2005 planting. The goal will be to reduce the collection to the most desirable 15 to 20 selections for further evaluation.

CONCLUSIONS:

No one rootstock will provide the optimum trees size, yield, fruit size, and quality for all cultivars or under all climatic, pathogenic, or insect regimes. Choices must be made based on location, soil condition, cultivar, and known insect and disease pressures. Generally trees on OHxF rootstocks have increased yields as compared to trees on seedling Bartlett roots. Winter Nellis seedling or Betulaefolia rootstocks appear to offer superior performance for Bartlett trees. No one OHxF rootstock is best for all cultivars. The use of interstems can reduce tree size, increase fruit size, and productivity. The Horner rootstock series shows promise for producing rootstocks, which offer some dwarfing characteristics while increasing yield and fruit size. Budding height affects canopy size and production. Too little is known about the budding height effect with different rootstocks and cultivars to even suggest a change in propagation practices at this time. Several new trials have been established as material became available. These trials are one to three years old, and so far none of the rootstocks have been shown to be significantly superior.

CONTINUING PROJECT **YEAR: 2/3**

TITLE: Northwest Pear Rootstock Trial

PROJECT LEADER: Eugene A. Mielke, OSU, MCAREC
Dana Faubion, WSU, Extension Service, Yakima
Tim Smith, WSU, Extension Service, Wenatchee

COOPERATORS: Jim McFerson, WTFRC, Wenatchee
Tom Auvil, WTFRC, Wenatchee

JUSTIFICATION AND SIGNIFICANT FINDINGS:

The pear industry in the Northwest needs a rootstock that can produce large, high quality fruit. This rootstock needs to be precocious, to allow for the early bearing, and still be able to produce large crops of high quality fruit through its mature bearing years. Some amount of dwarfing character is desirable, in order to have orchards which can be efficiently managed from the ground or with short ladders, and newer equipment that is more environmentally friendly. Ideally, the rootstock should be resistant (or at least tolerant) to the pests and diseases that plague Northwest growers.

There are numerous new pear rootstocks emerging from breeding, development, and/or evaluation programs around the world. In some cases these are being propagated and sold around the world with little testing beyond that done at a local level. In other cases fairly extensive testing has been done in areas with climatic, pathogenic, and/or insect regimes.

With very few exceptions *Pyrus* germplasm may not enter the United States, even under a post-entry quarantine permit, unless the material is evaluated through a virus-indexing and/or heat therapy program in the United States. The result is that it can take a number of years for scientists to get rootstock material of interest from other parts of the world. Additionally, many of the selections of interest have been difficult to propagate, thus requiring more time before they could begin to be tested under field conditions.

Several of these new rootstocks are now available for testing. The purpose of this project is to develop replicated trials of these new rootstocks in the Hood River Valley, the Tonasket area of the Okanogan, the Wenatchee River Valley, and the Yakima district. The trial would be established in two phases in 2002 and 2004. Additionally, two new cultivars (Concorde and Taylor's Gold) would be propagated on two rootstocks and established near the major rootstock trials in 2004.

OBJECTIVES:

To develop a rootstock that is precocious, produces large crops of high quality fruit, has some amount of dwarfing character, in order to have orchards which can be efficiently managed from the ground or with short ladders and newer equipment that is more environmentally friendly, and ideally resistant (or at least tolerant) to the pests and diseases that plague Northwest growers.

1. Assess rootstocks for dwarfing and semi-dwarfing characteristics, precocity, production, and fruit quality under varying soil and climatic conditions in the Northwest utilizing conventional rootstocks, interstems, and newly available rootstock material.

2. Determine the adaptability of Concorde and Taylor's Gold with two rootstocks in the Pacific Northwest.

PROCEDURES:

Objective 1: Assess rootstocks for dwarfing and semi-dwarfing characteristics, precocity, production, and fruit quality under varying soil and climatic conditions in the

Northwest utilizing conventional rootstocks, interstems, and newly available rootstock material.

Maintain d'Anjou plantings in Hood River and Cashmere, a Bartlett planting in Parker, and a Golden Russet Bosc planting in Tonasket. The following trials will be maintained or established:

1. Prepare site for phase I planting of the Northwest pear rootstock trial. Rootstocks will include: Pyrodwarf, Pyro II (2/33), Fox 10, Fox 11, 708-36, OHxF 87, OHxF 40 – plant in 2002, terminate 2011.

2. Prepare site for d'Anjou planting as second part of Northwest pear rootstock trial. Rootstocks will include: Brossier (28-152), Retuzier (OH11), Horner (H-4, H-10, & H-51), BM-200 (Australia), INRA P-2532, *Pyrus heterofolia*, and OHxF 87. – plant 2004, terminate 2013.

The experimental design will be a randomized complete block design with 10 blocks. The spacing will be wide enough to minimize the chance of tree interactions within the life of the experiment (10 years), but will need to fit within the grower's orchard. Pollinizers will account for 20% of the trees; placement will be every 5th tree in each row. Pollinizer placement in adjoining rows will be staggered (i.e. 1st, 6th, … tree in row 1; 2nd, 7th, … tree in row 2; etc.). Pruning and training will be consistent with that in the area and what the grower is using, including the utilization of a support system. If no overall support is planned, the trees will be supported only after they begin to lean to an unacceptable degree, and then the support will be similar to what a grower would employ.
Data to be collected annually will include: 1) Trunk cross sectional area (25 cm above bud union); 2) Canopy height, canopy spread (2 directions); 3) Flower clusters and fruit set (whole trees 1st five years); and 4) Yield (fruit number and total weight).

Additional data to be collected: 1) Planting time root system rating (1 to 5, poor to excellent), and TCSA; 2) Any observations as to insect or disease preference (we are not going to scout the blocks every week); and 3) Reason(s) for tree loss, if any.

Objective 2: Determine the adaptability of Concorde and Taylor's Gold with two rootstocks in the Pacific Northwest.

Establish Taylor's Gold and Concorde pears on OHxF 97 and Pyrodwarf rootstocks and establish them in conjunction with the 2004 rootstock trials as listed above. The procedures and data to be collected are as described above.

RESULTS AND DISCUSSION:

Tree combinations for the 2002 planting are currently being dug. They will be delivered in April. Propagation of the rootstock liners is well underway for the 2004 planting.

ESTIMATED DURATION:

Rootstock trials are evaluated for a period of 10 years and will terminate as shown above.

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BUDGET REQUESTED: 2002-2003
Funding 2001: $15,950
Title: Northwest Pear Rootstock Trial
Co-Principal Investigators: Eugene A. Mielke, OSU – MCAREC
Dana Faubiou, WSU – Yakima County Coop Extension Service
Tim Smith, WSU – Wenatchee County Coop Extension Service

Mid-Columbia Ag Res. & Ext. Center			
Salary & Wages			
Research Assistant, 0.085 FTE (12 mos.)	$2,583		
OPE	1,095		
Sub-Total Salary and Wages		$3,678	
Service & Supplies		1,200	
Travel		500	
Sub-Total (Mid-Columbia Ag Res. & Ext. Center)			$5,378
Yakima County Coop Extension Service			
Salary & Wages			
Data (2 people, 2 days = 32 hr @ $12.50)	400		
Sub-Total Salary and Wages		400	
Service and Supplies		200	
Travel		200	
Sub-Total (Yakima County Coop Extension Service)			$ 800
Wenatchee County Coop Extension Service			
Salary & Wages		0	
Sub-Total Salary and Wages		0	
Service and Supplies		0	
Travel		400	
Sub-Total (Wenatchee County Coop Extension Service)			$ 400
Total			$ 6,578

CONTINUING PROJECT REPORT

Project Title: Propagation of tree fruits and nuts

PI: Dr. William M. Proebsting, Department of Horticulture, OSU
Corvallis, OR 97331-7304

Cooperator: Dr. Gene Mielke, Mid-Columbia Research & Extension Center
Hood River, OR

Objectives: This project conducts research in propagation of pear, cherry and hazelnut to: 1) help the flow of new germplasm through research towards commercial propagation, 2) improve propagation of these species, 3) maintain several dozen clones in the field and in tissue culture and 4) study shoot regeneration and genetic transformation of cherry.

Significant Findings:
1) **Horner series**. Softwood cuttings from 304 clones in the Horner collection at Hood River were propagated at Corvallis in July. Of these, 294 clones had two or more rooted cuttings which will be grown and grafted at Fowler Nursery.
2) **East Malling series**. Liners of clonal rootstocks 517-9 and 708-13 will be sent to Hood River in spring, 2002.
3) **Russian clones**. In February, we are planning to receive budwood from three clonal rootstocks from Russia for initiation in tissue culture.
4) **Micropropagation**. Successful use of double-phase tissue culture of pear depends on the BAP (cytokinin) content of the liquid phase.

Methods:
Softwood cuttings. Cuttings were collected from the original seedlings growing at Hood River. These trees were pruned hard in spring, 2001 to induce vigorous shoot growth. All available cuttings from each stock plant were collected during two trips on 22 June and 5 July. Cuttings were prepared by removing the expanding shoot tips and then making 10" cuttings, except for dwarf clones for which 6" cuttings were made. The cutting bases were dipped for 5 sec in 100 mM IBA dissolved in 0.25 M KOH and planted in medium (perlite:peat, 3:1) in bands 2 ¼" squares by 5" deep at 22°C. The mist conditions were: 0700-0900 hours, 24 min interval, 0900 to 1000, 16 min interval, 1000 to 1700, 8 min interval, 1700 to 1900, 16 min interval and 1900 to 2000, 24 min interval. All mist applications were 10 sec duration.

During the last week of August, rooting was evaluated by tugging firmly on each cutting. The rooted cuttings were consolidated and moved directly outdoors to a shade structure.

Micropropagation. Pear clones were established in sterile culture by surface sterilizing actively growing shoots in 10% bleach solution and planting the shoots on DKW medium consisting of 0.8% agar, 3% sucrose plus DKW salts and vitamins. Shoots which were sterile and still actively growing were transferred to a multiplication medium consisting of DKW medium plus 1 ppm benzylaminopurine (BAP). Every 4-6 weeks, shoot clumps were divided into single shoots and re-cultured on

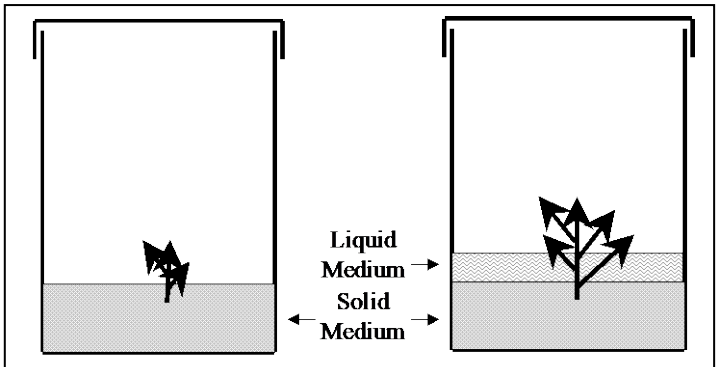

Figure 1. Single-phase vs. double-phase tissue culture.

multiplication medium.

When liquid medium is used in double-phase culture, enough liquid is added, about 25 ml, to nearly cover shoots that had just been divided and transferred.

When a sufficient number of shoots are available, the surplus is treated with indolebutyric acid (IBA) to stimulate rooting. Rooted shoots are transplanted into clean potting medium, grown under intermittent mist for two weeks and then transferred to the greenhouse. In the greenhouse, the shoots are grown to liner size and transferred to other research programs.

For transfer to commercial micropropagators, shoot cultures are sealed in sterile, plastic pouches containing a small amount of DKW solid medium and mailed to the nursery.

Results and Discussion:

1) **Horner series.** Gene Mielke is interested in testing production characteristics of this group of about 400 open-pollinated 'Old Home x Farmingdale' seedlings. Further testing was warranted when preliminary studies found some promising rootstocks.

In this situation, tissue culture of 400 clones is inappropriate. Since these are seedlings and have been maintained as small, heavily-pruned trees, rooting potential of softwood cuttings of each clone should be near its maximum. Furthermore, since only 2-5 liners of each clone were required for the rootstock trial, low rooting percentage was not a major obstacle. The two liner minimum was met by 294 of the 304 clones we sampled. In fact, this sample of clones was strongly skewed towards high rooting percentages (Figure 1).

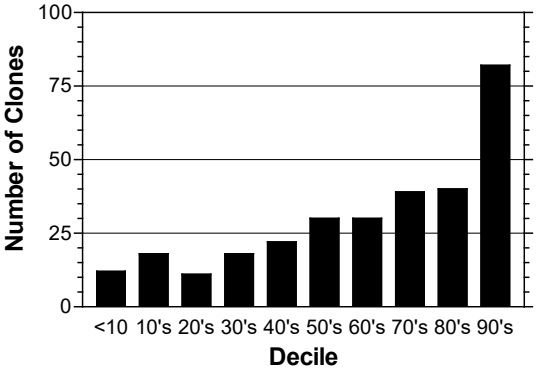

Figure 1. Frequency of rooting percentage for the Horner series clones propagated summer,

In late August, the rooted cuttings were moved outdoors to a shade structure and entered dormancy. In January, 2002, 2-5 of each clone will be shipped to Fowler Nursery for growing on and grafting, then eventual transfer to Hood River.

2) **East Malling series.** Two years ago, two additional clones, 708-13 and 517-9 were identified from the HRI rootstock breeding program. These were sent to NRSP-5, Bill Howell released them to OSU and we initiated them into tissue culture spring, 2000.

These clones multiply moderately well, but we have found they are difficult to root. Still, we have liners to send to Hood River this spring for testing.

3) **Russian rootstocks.** Several years ago, three clonal pear rootstocks were imported from Russia by Californians Larry Rogers and Jim LaRue. They are purportedly dwarfing. APHIS appears to be willing to make these available for preliminary propagation. Gene Milbrath of Oregon Department of Agriculture is helping me obtain the necessary paperwork. I expect to receive budwood in February, bud it to seedlings in the greenhouse and initiate cultures in spring, 2002. Thereafter, release of liners for testing will depend on certification by APHIS.

4) **Micropropagation.** Use of a double-phase system of micropropagation markedly stimulates shoot multiplication. We have done a series of experiments with double-phase in an effort to determine the components that make it work. For pear, shoot growth responded to BAP content of the liquid phase (Table 2).

Table 1. Effect of liquid phase composition on shoot growth of Fox 11.

Treatment		Multiplication
Single-Phase		
	Untransferred	5.2
	Transferred intact to fresh medium	6.2
Double-Phase		
	Water	4.9
	Hormone-free	5.3
BAP	1 ppm	3.8
	2.5	10.7
	5	13.7
IBA	0.01 ppm	3.2
	0.1	3.7
	1	4.1
GA_3	0.01 ppm	3.5
	0.1	4.6
	1	3.7

When we vary BAP content in either the solid or liquid phase, the highest multiplication rates occur when BAP is in both phases (Figure 2). However, multiplication is more responsive to BAP in the liquid phase than in the solid phase.

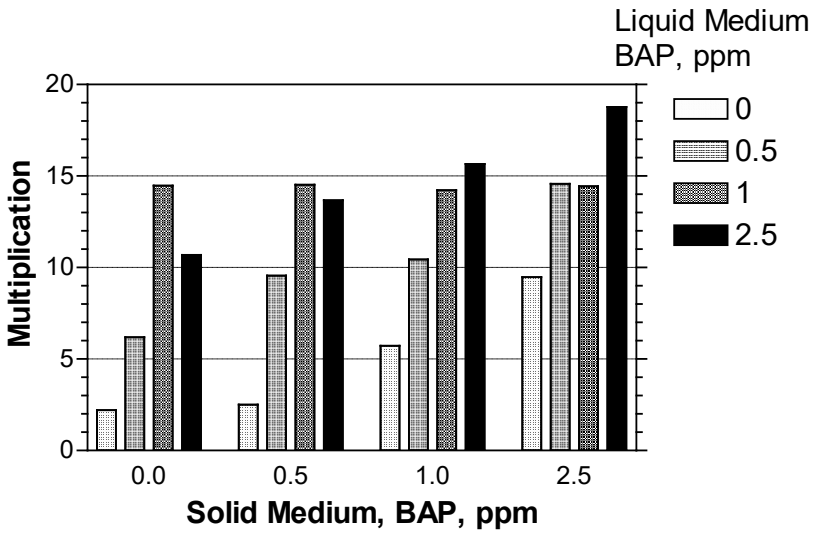

Figure 2. Effect of BAP content in solid and liquid phase on multiplication of Fox 11 shoots.

Budget:
Propagation of tree fruits and nuts
Dr. William M. Proebsting
Current Year: 2002-2003

Year	2000-01 (past)	2001-02 (current)	**2002-03 (proposed)**
Total	49,978	50,903	**50,497**[1]
Pear Request	26,903	26,903	**23,896**

Details

	2000-01	2001-02	**2002-03**
Salary, Faculty Research Assistant[2]	26,636	27,972	**28,531**
OPE	14,117 (53%)	13,706 (49%)	**14,266 (50%)**
Student Wages[3]	4,500	4,500	**4,000**
OPE	360 (8%)	360 (8%)	**200 (5%)**
Services and Supplies	4,000	4,000	**3,000**
Travel[4]	500	500	**500**
Total	49,753	50,903	**50,497**[1]

[1] This is the total amount requested to support the entire program, which includes filberts, cherries and pears.
[2]Luigi Meneghelli, Research Assistant
[3]Undergraduates maintain most of the cultures and field plots
[4]Travel to plots at the Lewis-Brown Farm

Details for Pear Request:

	2002-03 (proposed)
FRA	**13,552**
OPE (50%)	**6,776**
Student Wages	**1900**
OPE (5%)	**95**
Supplies	**1,425**
Travel	**238**
Total	**23,896**

CONTINUING PROJECT **YEAR 2/3**
WTFRC Project # PR-01-88

Title: Use of Hexanal Vapor for Aroma Production and Decay Control

PI: Peter Sholberg, Paul Randall, AAFC-PARC, Summerland, British Columbia

Cooperator: Peter Sanderson, WTFRC, Wenatchee, WA

Objectives:

1. Identify optimal hexanal concentration, temperature, and duration required to control *Penicillium expansum* (blue mold), *Botrytis cinerea* (grey mold), and *Mucor piriformis* (Mucor rot).

Preliminary experiments with naturally contaminated Anjou pears were initiated in winter and spring of 2001. Hexanal fumigation reduced both blue and grey mold decay of Anjou pears stored for 2 months. Mucor rot was not present in these samples. These preliminary experiments were with 4 mg/L hexanal for 72 hrs at 0EC. Further research is necessary on establishing the best concentration, temperature, time combination.
In September 2001 Trevor Shephard who had been leading this project resigned his position and Paul Randall took over his responsibilities. It will take Paul a few months to become completely familiar with this project.
Since Paul took over our first goal was to determine the conditions under which hexanal fumigation would burn pears and the second goal was to determine if it will control post harvest pathogens in wounds. If we find it does not control these types of infections we will concentrate on its use for sterilizing fruit surfaces.

2. Determine optimum concentration and length of exposure required to fumigate pears in commercial storage rooms.
Two bins of Anjou pears from Wenatchee and one bin from Summerland were fumigated in September, 2001. The fruit had just been harvested. Immediately after fumigation the pears were placed in standard pear boxes and stored at 1EC. These pears will be evaluated for decay in March, 2002. More commercial storage tests will be conducted in 2002 based on information we gain in conducting small trials during the winter of 2002.

3. Determine effect of hexanal fumigation on stored pear taste and aroma.
The aroma of fumigated fruit is very fruity and not unpleasant. Its taste may be improved by hexanal treatment. The use of a panel to accurately evaluate aroma and taste has been deferred until we have determined the most likely treatment rates. If time permits a panel will be conducted in the spring of 2002 to evaluate the effect of hexanal on aroma.

4. Evaluate the potential for combining hexanal with 1-methylcyclopropene (MCP) to control post harvest decay and improve pear aroma.
Preliminary experiments have been done with Gala apple. The method of treatment with hexanal and MCP did not present any problems. In the fall of 2002 an experiment similar to the apple trial will be conducted with Anjou pears.

Significant Findings:

- Hexanal fumigation of naturally contaminated Anjou pears reduced blue mold decay after the fruit had been stored for 5 months without any sign of phytotoxicity.

- Hexanal fumigation of naturally contaminated Anjou pears that had been removed from storage in March, fumigated, and stored for another 2 months reduced the level of grey mold decay.

- Hexanal fumigation of wounded and inoculated fruit at 1EC does not kill blue mold spores in wounds but at 21ºC spores in wounds are killed.

- Hexanal at concentrations above 8 mg/L at 1ºC is phytotoxic to pear fruit and causes black discoloration.

Methods

Small scale efficacy tests. Initial tests with hexanal have been done to verify that the methods used to measure its concentration are accurate. The GC used for measuring hexanal has been calibrated to accurately record rates of hexanal expected to be used in these experiments. Part per million of hexanal are calculated as for a gaseous solution and ppm hours are determined by multiplying this number by the number of hours of fumigation. Anjou pears are placed in the chamber and hexanal liquid is evaporated by heating with a small electric heater. Hexanal concentration during fumigation is determined by withdrawing samples of gas from the chamber via a septum shortly after the start and at regular intervals during fumigation until the chamber is vented and the fruit removed. The gas sample is injected into the GC and within approx. 5 minutes the concentration in the chamber is known. Tests to determine hexanal efficacy and phytotoxicity are done by wounding Anjou pears with a finishing nail and inoculating with a set number of spores (1 x 10^4 CFU/mL) of a decay-causing fungus, or blowing spores over the fruit surface and wounding after fumigation. Chamber used for fumigation can be placed at temperatures ranging from 0 to 20 C to determine effect of temperature. Humidity in the chamber is maintained at or around 80%. Fumigated fruit is placed at 20EC for 5 to 7 days when decay and phytotoxicity are recorded.

Large scale efficacy tests. Three bins of Anjou pears, two from Wenatchee, WA, and one from Summerland, B.C. were split into half bins for use in a fumigation trial. Three half bins were fumigated with hexanal at 4 mg/L for 48 hours at 2EC. Hexanal concentration was monitored with a GC. After fumigation the pears were boxed and placed in cold storage (1ºC). These pears will be evaluated for blue mold, grey mold, and Mucor rot in April, 2002. In fall 2002 several bins of Anjou pears will be fumigated based on small scale tests above. They will be fumigated as they come into storage. If recommended by the industry we will combine hexanal fumigation with MCP.

Results and Discussion:

Large scale efficacy tests

Half bins of Anjou pears were fumigated with hexanal at 4 mg/L on 3 January, 2001. The results indicated that hexanal reduced blue mold decay caused by *Penicillium* spp. (Fig. 1).

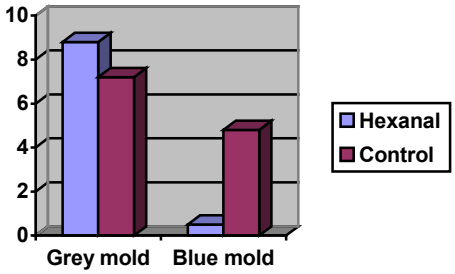

Fig. 1. Effect of hexanal on grey mold and blue mold decay. This is mean percent rot found in three half bins of Anjou pears.

This was the first preliminary experiment that was done in 2001 and rates and treatment conditions were estimated based on previous work with acetic acid fumigation and information found in the publication by Song et al. (1996). The experiment was done in order to gain experience with fumigating bin lots of pears with hexanal and find out if it would have any effect on decay of naturally contaminated fruit.

In March pears from Wenatchee (two grower lots) and Summerland (one grower lot) naturally contaminated by various mold pathogens were recycled from an experiment with acetic acid fumigation. This was another attempt at getting experience with hexanal fumigation . The fruit were fumigated at a rate of 4 mg/L at 0ºC for 72 hours and stored at 1ºC for 2 months. This experiment showed that hexanal reduced the number of fruit with mold at both locations (Fig. 2).

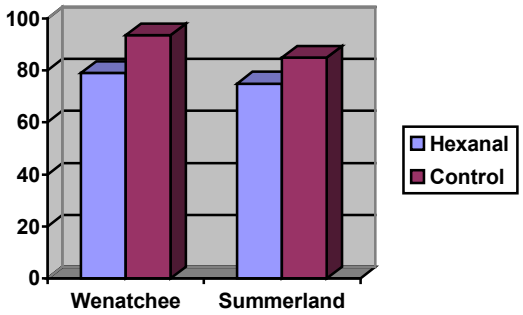

Fig. 2. Percent Anjou pears contaminated or infected with mold from two locations

These preliminary experiments supported our belief that hexanal could reduce post harvest decay in Anjou pears but would need further research on timing, rates, and application temperatures.

The above fumigations used pears that were either culls or of low quality and heavily contaminateded with mold when the fumigations were done. For this reason the experiment with the half bins was repeated in September 2001 with Anjou pears of high quality from both Wenatchee and Summerland. These pears were fumigated without problem and are presently in storage.

Small Scale Efficacy tests

Recent experiments have concentrated on fumigation of fruit wounded and inoculated with *Penicillium expansum.* This is the most challenging approach to take in evaluating effectiveness of a post harvest decay control product. TBZ (thiabendazole) provides control when wounds are contaminated but products like sodium hypochlorite only control surface borne pathogens. The tests were also designed to evaluate phytotoxicity of hexanal. In the early tests problems were encountered with accurate measurement of hexanal in the cubic meter chamber we were using. These problems were overcome and we established that a rate of 10 mg/L hexanal for 48 hours at 1ºC would burn Anjou pears. Fumigation at a rate of 4 mg/L for 24 or 48 hours would not burn the pears but did not control *P. expanusm* in wounds. Fumigation at 8 mg/L for 48 hours at 1ºC did not control decay but appears to have reduce the lesion diameters compared to the unfumigated control. It appears that in order to get optimum effectiveness of hexanal it will need to be used at warmer temperatures. This does not mean it will not control decay at lower temperatures but the amount of control will be less than what can be obtained if the fumigation could be done at a warmer temperature. The results below (Table 1) show that a rate of 4 mg/L for 48 hours at 21ºC will reduce decay of both pears and apples even when the fruit is wounded before fumigation. When the rate was lowered to 2 mg/L phytotoxicity was reduced in Gala and Golden Delicious apples but decay was not controlled. It is

interesting that the Anjou pears from Summerland did not show signs of phytotoxicity in these trials at 4 and 2 mg/L hexanal. One possible explanation is that they were less mature than the other fruit.

Table 1. Percent decay of fruit treated by hexanal fumigation at 4 mg/L for 48 hours at 21ºC

Fruit[1]	Control %Decay	Hexanal[2]	
		%Decay	%Phytotoxicity
Anjou (Wenatchee)	100	60	100
Anjou (Summerland)	97	67	0
Gala	97	77	100
Golden Delicious	100	67	70
Red Delicious	100	93	0

[1]Fruit were divided into two lots of 10 fruit with three wounds on each fruit. Percent decay is based on the number of infected wounds per 30 total wounds.
[2]Amount of hexanal applied was 12,551 ppm hours.

Budget Request:
Use of Hexanal Vapor for Aroma Production and Decay Control
Peter Sholberg[1]

Year	**2001-2002**	**2002-2003**	**2003-2004**
Salary	6,500	**6,500**	6,500
Materials and supplies	500	**500**[1]	500
Travel	500	**500**[2]	500
Total	7,500	**7,500**[3]	7,500

[1]Supplies include such items as petri dishes, GC supplies, pears, boxes, packs, and hexanal.
[2]Possible travel to Washington to treat pears at a packinghouse.
[3]Funds to be matched by the Matching Investment Initiative Program of Agriculture and Agri-Food Canada.

References

Song, J., Leepipattanawit, R., Deng, W., Beaudry, R.M. 1996. Hexanal vapor is a natural, metabolizable fungicide: Inhibition of fungal activity and enhancement of aroma biosynthesis in apple slices. J. Amer. Soc. Hort. Sci. 12:937-942.

CONTINUING REPORT

TITLE: Postharvest decay control

PI: Peter G. Sanderson, Plant Pathologist, WTFRC
WTFRC staff: Mark S. Aldrich, Diane Fuller, and Zhongzi Shao, WTFRC

OBJECTIVES:
Assess efficacy of new chemical and biological fungicides for control of postharvest decay
Assess new technologies for management of postharvest diseases and disorders

SIGNIFICANT FINDINGS (2000-2001):
Fungicide and SAR tests
Scholar

- Best control of blue mold in Delicious apples and Anjou pears was achieved with at rates 12-oz/100 gal (96% control) when used as a line spray.
- In conditions with low disease pressure, drenches were as effective at 2-oz/100 gal as at higher rates (up to 16-oz/100 gal) but the efficacy of Scholar may be adversely affected by dirt and debris that accumulates in drenches.

JAN PL-40 (PH066)

- Very effective against blue mold in apples at all rates tested.

Biological antagonists

- Blue mold control by two of three yeast biological control antagonists tested was unaffected by the amount of pathogen inoculum ($3x10^3$ to $3x10^4$ CFU/ml) they were challenged with, whereas, disease incidence in fruit treated with the third antagonist was twice as high at the high inoculum dose than at the low dose.
- Disease incidence in fruit treated with high concentrations of yeast antagonists was not affected by pathogen dose whereas incidence in fruit treated with lower concentrations were.

Biox 10/10

- Not effective at reducing scald in apples and pears when applied as a cold dip.

Citrox

- Postharvest drenches significantly reduced the amount of postharvest decay in Fuji (1.1% vs. 3.7% of fruit decayed) but not in Golden Delicious or Anjou.

Messenger

- Appears to advance senescence of both pears and apples when applied in the field and to a lesser extent as a postharvest drench.
- In Anjou pears and Fuji apples, differences in maturity indicators (fruit firmness, starch index, titratable acidity, soluble solids) among pre-harvest treatments were not apparent at harvest.
- Overall incidence of decay in Anjou pear fruit was not significantly affected.

Fungicide resistance in Penicillium expansum

- Of 252 isolates of *P. expansum* collected from the field, 10.7% were resistant to TBZ.
- All isolates of *P. expansum* that were insensitive to TBZ at 1.0 ppm also were resistant at 1000 ppm.
- TBZ resistance was orchard specific. Up to 20% of isolates from some orchards were resistant while none were resistant in others.
- No resistance to imazalil or fludioxonil was observed.

Hypochlorite drenching

- Decay was lowest in bins of fruit treated with calcium hypochlorite and highest is those treated with sodium hypochlorite.

- Phytotoxicity of sodium hypochlorite, especially at 250 ppm, may have increased susceptibility of fruit to disease.

Sanitation

Chlorine dioxide

- Electrochemically generated chlorine dioxide effectively suppressed inoculum in a cold water dump tank at 2.5 ppm chlorine dioxide with no off-gassing. However, off-gassing occurred when the system was used on a warm water tank.

Pressure washing

- Decay incidence and severity increased with increasing pressure.
- Scald-like symptoms developed in response to increasing pressure (SI=11.5 at <10 psi to SI=70.1 at 160 psi) in fruit that had been stored for about 8 mo.

Application technology

Thermofogging

- Thermofogging was effective for application of DPA and ethoxyquin to Granny Smith apples and Anjou pears, respectively.
- OPP applied by thermofogging was ineffective at reducing decay.

RESULTS AND DISCUSSION:

Fungicides and SARs

Efficacy of Scholar for postharvest disease control. Line sprays and drench applications were used to establish effective concentrations of Scholar on apple and pear fruit. The interaction of dirt and debris that accumulates in normal drenching operations with Scholar was also examined.

Line sprays. Line spray applications of Scholar significantly reduced blue mold in both Delicious apples and Anjou pears at all rates tested (2, 4, 8, 12, and 16 oz/100 gal.). Best control was achieved with rates ≥ 12-oz/100 gal (96% control).

Drenches. Similarly, drench applications to both unwounded and artificially wounded Anjou pears reduced decay incidence at all rates tested, but no difference was apparent among rates (about 93% control). Gray mold incidence and that of other postharvest diseases (e.g., bull's-eye rot and Alternaria rot) were low in the unwounded, drenched fruit (0.4% and 0.14% of fruit decayed, respectively) and were not affected by Scholar treatments.

Disease incidence in Delicious apples drenched with Scholar mixed with dirty drench water was low in unwounded fruit. Only 2.1% of fruit were diseased in the control (0 ppm Scholar). All levels of Scholar reduced decay incidence to ≤ 0.2%. Incidence of blue mold and other postharvest diseases were reduced to < 0.1%.

However, decay control was differentially affected by either the rate of Scholar used or the order in which fruit were drenched in wounded fruit. Considerably less decay (7.5%) developed in fruit treated with the lowest concentration of Scholar (2-oz/100 gal) than in those treated with higher concentrations (about 24% of fruit decayed). This effect is counter to that observed in the line spray trials; decay control was proportional to Scholar concentration. In this trial fruit were treated in order of concentration from lowest (no fungicide) to highest (16-oz/100 gal). The reason for the differential in decay control at succeeding concentration is not clear. It may be that Scholar reacted to components of the drench mixture (i.e., soil, DPA, TBZ, or other accumulated materials) and that the reaction, begun at the lower rate, proceeded at a faster rate once catalyzed and as additional Scholar was added. This effect was striking and consistent and warrants further investigation.

Efficacy of Janssen PL-40. JAN PL-40 effectively eliminated (100% control) blue mold and gray mold in inoculated wounds in Delicious apples at all concentrations tested (200-1000 ppm). In comparison, Fungiflor (imazalil) controlled 97.4% of blue mold lesions and 85.9% of gray mold lesions. TBZ controlled 86.9% of blue mold lesions and 98.8% of gray mold lesions.

Efficacy of three biological antagonists for postharvest disease control. Three biological antagonists from Dr. Wojciech Janisiewicz, USDA-ARS, Kearneysville, WV, were tested for their ability to prevent infection by *P. expansum* in Anjou pear and Red Delicious apple fruits. Efficacy of each antagonist was differentially affected by the concentration of pathogen inoculum it was challenged with (either 3,000 spores/ml, 9,000 spores/ml, or 30,000 spores/ml). Disease incidence in fruit treated with antagonists Kwj-2 and Kwj-4 was unaffected by pathogen dose (19.5 % and 31.6% of fruit with lesions, respectively). Whereas disease incidence in fruit treated with isolate Kwj3 was over twice as high when challenged with the high dose of pathogen spores (35% of wounds with lesions) than with the lower doses (11.3% of wounds with lesions).

In addition, the number of lesions that developed in fruit was affected by the concentration of antagonists relative to pathogen concentration. For example, little difference in efficacy was observed at the highest antagonist concentration (75% transmittance) regardless of pathogen concentration (about 16.2% of wounds with lesions), but less than half as many wounds developed lesions at the lowest pathogen dose (3,000 spores/ml) than at higher concentrations (9,000 and 30,000 spores/ml) at an antagonist concentration of 85% transmittance.

Efficacy of Biox 10/10 for scald and decay control in pear and apple fruits. Neither decay incidence nor superficial scald in Anjou pear, Granny Smith apple, or Red Delicious apple fruits were affected after treatment with 1.0, 2.0, or 4.0 g/L of Biox 10/10 applied as a dip. Fruit had been stored in RA and were assessed about 90 days after treatment.

Efficacy of preharvest treatment with GNS2000 and Citrox 14W drenches for postharvest decay control in apples and pears. Preharvest treatment with GNS2000 had no effect on postharvest decay in Anjou, Golden Delicious, or Fuji fruits after 6 mo (pears) or 7 mo (apples) in standard CA storage. Postharvest drenches of Citrox 14W significantly reduced the amount of postharvest decay in Fuji (1.1% vs. 3.7% of fruit decayed) but not in Golden Delicious or Anjou. Some phytotoxicity was evident in Anjou fruit drenched with Citrox 14W. Mucor rot developed in damaged fruit and disease incidence was significantly higher in drenched fruit (0.41%) than in untreated fruit (0.04%).

Efficacy of Messenger (Harpin protein). Anjou pears were treated either preharvest (3 wk and 1 wk before harvest, 1 wk preharvest or untreated) or with a postharvest drench (20 ppm a.i.). Fuji apples were treated with Messenger (13 g/A) applied with an airblast sprayer either full season long (7 applications), twice (3 wk and 1 wk before harvest) or left untreated or drenched postharvest (20 ppm a.i.). Messenger appears to advance senescence of both apples and pears when applied in the field and to a lesser extent as a postharvest drench. This had significant effects on fruit storage with loss of quality (e.g., firmness and acidity) and increased decay potential compared to untreated fruit.

Anjou pears-maturity and senescence. Similar to that seen in Fuji apples, differences in maturity indicators (fruit firmness, starch index, titratable acidity, and soluble solids) among pre-harvest treatments were not apparent at harvest. However, by 3 mo after harvest fruit treated twice preharvest with Messenger were 1.5 lb softer than those in the other treatment groups. These fruit continued to soften so that by the conclusion of the test (5 mo after harvest) they were 2 lb softer than untreated fruit. In addition, drenched fruit were about 1.5 lb softer than untreated fruit at the last assessment date. During the course of this study no effect on acidity and only a slight effect on soluble solids 3 mo after harvest were discerned.

Fuji apples-maturity and senescence. No significant differences among maturity indicators (firmness, titratable acidity, and starch index) were apparent at harvest. However, a strong trend was apparent in which apples treated with Messenger season long appeared to be more mature (higher starch index and less firm) than untreated fruit and those treated only twice before harvest. These differences became more apparent and statistically significant with length of storage. By 2 mo after harvest, fruit treated throughout the season were significantly softer (about 1 lb) than fruit that were not treated in the field. Firmness and acidity values observed in fruit treated 3 wk and 1 wk before harvest trended to being lower than fruit not treated in the field and were not significantly different from either the untreated or season-long treated fruit. In addition, watercore, sunburn, and stain

indices were higher in field treated fruit than in untreated and drenched fruit. Postharvest drenching with Messenger alone had no effect fruit senescence.

Decay. Overall decay incidence in Anjou fruit was not significantly affected by Messenger treatments. However, blue mold incidence was significantly higher in fruit treated twice in the field (1.3% of fruit with symptoms) than in other treatments (about 0.2% of fruit with symptoms). Neither Gray mold nor Mucor rot was significantly affected by Messenger treatment even though the incidence of each was numerically greater in fruit treated twice preharvest. The increase in blue mold is probably a reflection of the advanced senescence observed from that treatment. Over mature and senescent fruit have increased susceptibility to decay from most postharvest diseases.

Fungicide resistance in Penicillium expansum. Field isolates of *P. expansum* were collected from fruit, soil, leaf litter, and fruit bins in seven orchards and grown on agar containing 0.0, 1.0, 10.0, 100.0, or 1000.0 ppm of either TBZ, fludioxonil, or imazalil. Of 252 isolates tested, none grew on agar amended with fludioxonil and imazalil at any concentration. However, 10.7% of isolates were insensitive to TBZ at all concentrations. Strong orchard effects were observed in which 18-20% of isolates were resistant in three orchards, 5% in one orchard and 0% in three orchards. Colony diameters of isolates resistant to TBZ were somewhat smaller when grown on agar with ≥ 10 ppm TBZ. TBZ sensitive isolates (no growth at 1.0 ppm) were also placed on agar containing 0.1 ppm TBZ. All isolates (119) grew at this concentration, but colony diameters were reduced compared to the 0.0 ppm control (21.0 mm diam vs. 24.9 mm diam, respectively. Only 36.1% of this group of isolates grew on media amended with 0.1 ppm imazalil (0.5-14 mm diam) after 5 days and only 3.4% of isolates grew (0.5-1.0 mm diam) on 0.1 ppm fludioxonil amended media after 5 days.

Effect of hypochlorite drenching on Anjou pear quality. Bins of Anjou pear fruit were drenched with 100 ppm or 250 ppm of calcium hypochlorite or sodium hypochlorite, or water, all at pH = 7.1. Disease incidence and phytotoxicity were assessed about 5 mo after treatment and RA storage at 31 F. Decay, caused mostly by *Botrytis cinerea* followed by *P. expansum*, was lowest in bins of fruit treated with calcium hypochlorite and highest is those treated with sodium hypochlorite. Data suggest that phytotoxicity of sodium hypochlorite, especially at 250 ppm, may have increased susceptibility of fruit to disease.

Sanitation

Efficacy of electrochemically generated chlorine dioxide for dump tank sanitation. Tests with the Halox 2000 were repeated in a packinghouse that was running fruit with a heated dump tank. Chlorine dioxide off-gassing was immediately detected. Presumably the major difference between systems was the water temperature. Cold water (about 36 F) was used in the first test; warm water (about 80 F) in the second. Although in the first tests with the system we observed good inoculum suppression, the technology does not appear to be suitable for commercial use.

Effect of pressure washing on Anjou pear decay. Anjou pears were sprayed with water seeded with spores of *P. expansum* (3000 conidia/ml) pumped at high pressure through spray bar similar to those used on fruit packing lines. In two trials using fruit that had been in commercial CA storage for 8 and 9 mo, respectively, fruit was treated for 1 min with water at <10, 60, 80, 100, 120, 140, or 160 psi. Decay incidence increased with increasing pressure from about 12 % of fruit with lesions at <10 psi to about 51% of fruit affected at 160 psi. In addition, scald-like symptoms developed in response to increasing pressure (SI=11.5 at <10 psi to SI=70.1 at 160 psi).

In a third trial using new crop (2001) fruit in which fruit were treated with water at 0, 10, 60, 80, and 100 psi for either 8, 12, or 16 s, disease incidence was significantly higher at 60 psi than at 0 psi (17% vs 27% of fruit affected, respectively) regardless of the length of time fruit were exposed. Incidence did not increase significantly beyond that. However, disease severity (number of lesions on each fruit) increased with increasing pressure from about 0.2 lesions/fruit to 0.5 lesion/fruit at 0 and 100 psi, respectively. No scald-like symptoms were observed.

Postharvest chemical application technology

Application of postharvest chemicals by thermofogging. Anjou pears. Postharvest applications of either corn oil (500 ml and 1000 ml) or ethoxyquin (Xedaquine-A, 426 g) plus OPP (Xedol-A, 426 g) applied by thermofogging were compared to conventional drench applications of corn oil emulsion (2.5% and 5%), corn oil emulsion (5%) plus SOPP (800 ppm), ethoxyquin (1500 ppm) plus SOPP (800 ppm) and an untreated control. Treatments were applied to four single replicate bins of Anjou pears within 2 wk of harvest. Fruit was stored under standard RA conditions for about 6 mo then decay incidence and superficial scald was assessed.

Residues of OPP were assessed immediately after treatment from fruit removed from the center of each bin. Significantly higher OPP residues were detected in thermofogged fruit than in drenched fruit (1.79 ppm vs. 0.83 ppm in thermofogged fruit and drenched fruit, respectively). Incidence of decay, phytotoxicity, and superficial scald index all were significantly affected by treatments. Overall decay incidence was reduced from 14.4% in untreated fruit to 1.3% in fruit drenched with SOPP and ethoxyquin, but was not significantly affected by the other treatments. Most of the decay was caused by gray mold. Gray mold incidence was significantly affected by both treatments in which SOPP was applied as a drench, but not by the other treatments. Superficial scald was significantly reduced in those treatments in which ethoxyquin was applied either by drenching (SI = 13.3) or fogging (SI = 15.2) compared to the untreated control (SI = 53.6). Scald index was not affected by the other treatments.

Granny Smith apples. DPA (Xedamine, 2220 g) and OPP (Xedol-A, 888 g) were applied to each of four single replicate bins of Granny Smith apples by thermofogging and were compared to conventional drench applications of SOPP (800 ppm) and DPA (2200 ppm) and an untreated control. All treatments were made using the Stemilt RCA facility in Wenatchee, WA. Treatments were applied within 1 wk of harvest. Fruit was stored under standard RA conditions for about 6 mo at which time decay incidence and superficial scald were assessed.

Chemical residues, especially OPP, were higher in fogged fruit than in drenched fruit and the top layers of fruit in the upper bins were badly burned. OPP residues in fogged fruit were about 14.6 ppm, whereas they were undetectable in drenched fruit. Residues of DPA also were significantly higher in the fogged fruit (3.5 ppm) than in the drenched fruit (1.04 ppm). It is likely that the elevated OPP residues caused the burning observed; DPA residues were within acceptable limits. No scald developed in any of the treatment groups, probably because all bins were stored together in the room in which fruit were fogged. Although the room was aired out before bins were placed in it, there was probably enough DPA coating the walls and bins that it volatilized and migrated to the untreated fruit. Decay incidence was low (about 0.5%) and was not significantly affected by any of the treatments.

PROPOSED RESEARCH:

Chemical and biological control remain mainstays of postharvest disease management programs. New chemicals from several companies are being developed for postharvest use and for preharvest application to control postharvest disease. We are continuing to provide data to registrants on the efficacy of these chemicals to promote their further development and registration. The use of biological antagonists for postharvest disease control is the only option for organic production and has been embraced as a supplement conventional disease management programs. Single organisms are typically developed for use as biological antagonists. However, combinations of antagonists that more effectively utilize space and nutrient resources may enhance their effectiveness.

Niches on fruit and leaf surfaces that can support populations of biological antagonists are scattered. Assays to determine density of populations of *Penicillium* spp. on fruit in orchards in which molasses had been applied yielded large populations of yeasts. It may be possible to enhance efficacy of field applied biological antagonists against postharvest diseases by applying nutrients with the antagonists. The contribution of field bins to inoculum loading of drenches and packinghouse water systems has been established.

Sanitation is another mainstay of postharvest disease management. The contribution of field bins to inoculum loading of drenches and packinghouse water systems has been established. Practical methods for sanitizing bins need to be developed and implemented. The fruit industry is adopting pressure washers to remove field residues such as Surround. Most systems use of recirculated water that can become heavily contaminated with pathogen spores and increases the probability of incurring disease losses. Methods to minimize spore loading in those water systems need to be developed and tested.

Trials planned or currently underway include:

Fungicides and SARs

- Efficacy of BAS 516 against blue mold - dips and line sprays,
- Efficacy of Scholar against blue mold in combination with wax and antioxidants - line sprays,
- Efficacy of JAN PH066 against blue mold and gray mold - dips and line sprays,
- Effects of different formulations of JAN PH066 on fruit quality - line sprays,
- Interaction of TBZ with Surround – dips.
- Crop Life 2000 - field applications.
- Efficacy of combinations of Biosave, a bacterium, and CIM, a yeast, against blue mold.
- Nutrient enhancement of field applied biological antagonists against postharvest pathogens.
- Combinations of Biosave, a bacterium, and CIM, a yeast, will be assayed for efficacy against blue mold.

Sanitation

- Bin sanitation to eliminate fungicide resistant and residual populations of postharvest pathogens.
- Develop and test new methods for sanitizing water used in pressure washers.
- Efficacy of SOPP and chlorine with new pear floats

Postharvest chemical application technology

- Efficacy of fungicides and antioxidants applied by aerosols
    - Xeda: TBZ, JAN PH066, Scholar, Imazalil, and Eugenol

BUDGET:
Post Harvest Decay Control
Peter Sanderson

:	2000	2001	**2002**	
	WTFRC	WTFRC	**WTFRC**	Outside funding
Timeslip wages	5000	5000	**5,000**	
Timeslip benefits	800	800	**800**	
Goods and services[1]	5000	5000	**5,000**	15,000 [2]
Travel[3]	500	500	**750**	
Total	11,300	11,300	**11,550**	15,000
[1] Fruit, agric. chemicals, lab supplies, [2] Estimated from chemical companies; [3] In-state travel to orchard plots and packinghouse				

CONTINUING REPORT

TITLE: Blue mold epidemiology

Principal investigator: Peter G. Sanderson, WTFRC, Wenatchee, WA
Cooperators: Diane L. Fuller, WTFRC, Wenatchee, WA
Auvil Fruit Company
Bardin Farms
Stemilt Management

OBJECTIVES FOR 2001:

Determine environmental, temporal, spatial, and biological parameters that favor inoculum production and dispersal of blue mold causal agents (especially *P. expansum* and *P. solitum*) in the field, fruit storage and packing houses.

- Determine sources of field bin contamination.
- Determine relative population densities of *Penicillium* spp. in leaf litter, soil, and orchard debris over time.
- Determine substrates that favor growth of *Penicillium* spp.
- Determine effects of selected environmental parameters on growth and dispersal of *Penicillium* spp.
- Determine sources of packinghouse contamination.

OBJECTIVES FOR 2002:

Same as for 2001 with refinements based on current findings as discussed below.

SIGNIFICANT FINDINGS:

1. Populations of *Penicillium* spp. on new bins increased over time in the orchard.
2. On an area basis, new wood bins held up to 3,000 X more spores of *Penicillium* spp. than did new plastic bins after several weeks in the orchard. However, there was little difference in population densities on a per bin basis.
3. Contamination of field bins rose during fruit storage.
4. Bins were further contaminated during immersion dumping where the packers had insufficient chlorine (i.e., < 100 ppm) in the dump tank water.
5. Isolates of *Penicillium* spp. survived in bin piles better on wood bins than on plastic bins.
6. Contaminated field bins appear to be a significant source of TBZ resistant isolates in the field.
7. Highest densities of *Penicillium* spp. in the field were found in leaf litter.
8. Frequency of recovery of *P. expansum* was most consistent in soil.
9. *P. expansum* grew in pasteurized top soil with water potential ≥ -5 bar.
10. *P. expansum* grew in small, decomposing pieces of leaf litter (<6 mm diam.) but not in coarse leaf litter.
11. Contamination of air in packinghouses appears to originate during dumping and handling of fruit in bins and during repacking.

RESULTS AND DISCUSSION:

- **Determine sources of field bin contamination.** New bins became contaminated with spores of *Penicillium* spp. in the field. Inoculum potential of wood bins was about 180 times higher than plastic bins (i.e., they collected many more spores). Only 6% of *P. expansum* isolates recovered from new bins were resistant to 100 ppm TBZ whereas about 60% of isolates recovered from old bins in 1999 were resistant. Fungi grew on bin surfaces in storage. In most cases bins were

further contaminated during immersion dumping where the packers did not have sufficient chlorine (i.e., < 100 ppm) in the dump tank water to kill fungal spores.

Field bins became contaminated with spores of *Penicillium* spp. in the field. Spore loads concentrated in dirty packinghouse water systems (i.e., drenches, dump tanks, and flumes) and lead to further contamination of bins. Apparently, spores can persist on the surface of bins and be carried back to the field the following harvest. These contaminated bins account for the majority of TBZ resistant isolates recovered and may be the source of development of TBZ resistant populations in the field.

1. Populations of *Penicillium* spp. on field bins at harvest, 2000.
   a. New wood and plastic bins were placed in four orchards to assess extent of contamination of bins from inoculum originating in the field.
      i. Populations varied greatly among orchards
      ii. Populations increased over time
      iii. Isolates of *Penicillium* spp. were recovered from 72% of wood bins and 62% of plastic bins.
         (1). Fewer isolates of *Penicillium* spp. were recovered from plastic bins than wood bins (#34.9 CFU/cm^2 on plastic bins vs. #6,497 CFU/cm^2 on wood bins).
         (2). Highest numbers of isolates were recovered from sides of bins in contact with the ground.
         (3). *Penicillium expansum* was recovered from 33% of wood bins and 31% of all plastic bins.
         (4). *Penicillium solitum* was recovered from 51% of wood bins and 33% of plastic bins.
      iv. Isolates *P. expansum* recovered from bins were tested for TBZ resistance (1 ppm, 10 ppm, 100 ppm, and 1000 ppm)
         (1). 6.0% of isolates were resistant to TBZ at all concentrations
         (2). Isolates were either resistant at all TBZ concentrations, or not at all
2. Populations of *Penicillium* spp. on field bins postharvest
   a. Population density of *Penicillium* spp. remained static on new wood bins and increased on plastic bins during CA storage.
   b. Populations of *Penicillium* spp. on most wood and plastic bins increased following dump tank immersion.
      i. Chlorine levels at three of the packing houses ranged from 10 – 30 ppm.
      ii. Bins at only one packinghouse, which used 130 ppm total chlorine in their dump tank at the time bins were run, did not show an increase in populations of *Penicillium* spp. after dumping.
   c. Populations of *Penicillium* spp. on bin surfaces dropped while bins were stored in outdoor bin piles, especially those on plastic bins. Wooden bins had almost 400 X more spores of *Penicillium* spp. surviving on them than were on plastic bins (4.4×10^7 CFU/bin vs. 1.2×10^5 CFU/bin, respectively).

- **Determine substrates that favor growth of *Penicillium* spp.** Population density of *Penicillium* spp. in the field was greater in leaf litter than in soil, but frequency of recovery was greatest in soil. *P. expansum* grew in pasteurized soil with water potential ≥ -5 bar. It did not grow in unpasteurized coarse (not decomposed) leaf litter over a range of moisture contents. However, *P. expansum* did grow in small pieces of heat treated leaf litter. The stage of decomposition at which *P. expansum* colonizes leaf litter and the effect of microbial antagonists on such colonization should be further investigated.

1. Field populations
   a. Leaf litter

i. Higher population densities were found in leaf litter than in soils.
ii. Exposure (shade) and moisture content on organic matter was positively correlated with population density of *Penicillium* spp.
iii. Highest populations of *Penicillium* spp. were found on mixed grass and broad leaf litter
iv. Highest populations were recovered from litter that was ≥ 1 yr old.

a. Soil
v. *Penicillium* spp. were recovered from 67% of samples collected from apple orchards.
vi. *Penicillium* spp. in soil were recovered in an aggregated distribution.
vii. Soil moisture and amount of organic matter included in samples was positively correlated with population density of *Penicillium* spp.

2. Artificial inoculations
b. Leaf litter
i. *P. expansum* did not grow in coarse orchard leaf litter inoculated and held at room temperature for 10 days over a wide moisture content range (2.4% to 193% water [wt:wt]).
(1). Leaves were not sterile and other fungi, especially *Alternaria* spp. and *Cladosporium herbarum*, were also present that may have competed with *P. expansum* for nutrients and space.
ii. Populations of *P. expansum* increased by 129% in decomposing leaf litter particles <6mm diam.
(1). Litter was screened and divided into different size groups (<6 mm, 6-12 mm, and >12 mm) and heated (150 F for 24 hr) to reduce populations of other fungi.

c. Soil
iii. Populations of *P. expansum* increased in top soil incubated at room temperature for 10 days at different soil water potentials.
(1). 96.0% increase at –1 bar, 46.4% increase at –5 bar, and 2.0% increase at –15 bar

- **Determine relative population densities of *Penicillium* spp. in leaf litter, soil, and orchard debris over time.** This work was initiated this spring and results have not yet been analyzed.

1. Field plots
a. 3 orchards (Orondo, East Wenatchee, Monitor)
i. Orchard soil population monitoring
(1). Weekly sampling
(2). Frequency of recovery from soil was most consistent in previous sampling (2000)
ii. Orchard air population monitoring
(1). Twice weekly sampling

- **Determine effects of selected environmental parameters on growth and dispersal of *Penicillium* spp.** This work was initiated this spring and results have not yet been analyzed.

1. Weather stations established in orchard sites
a. Data collected hourly
i. Soil and leaf litter temperature
ii. Air temperature and relative humidity
iii. Solar radiation
iv. Wind speed
v. Wetness periods

- **Determine sources of packinghouse contamination.** Contamination of air in packinghouses appears to originate during dumping and handling of fruit in bins and during repacking. Significant reduction of pathogen spores from packinghouse air could be achieved by simple measures such as installing fume hoods over the dump tank and segregation of repacking into areas that can be vented out of the packinghouse.

1. Airborne spores collected at 4 packing houses
   a. Samples collected from 12-17 locations within each packing house
   b. Spore density gradients were apparent within three of four packinghouses. High density areas centered around:
      i. Dump tanks,
      ii. Pressure washers,
      iii. Drying fans, and
      iv. Repack areas

BUDGET:
Blue Mold Epidemiology
Peter Sanderson

	2001	**2002**
Labor	20,000	**20,000**[1]
	3,200	**3,200**
Goods and services[2]	5,000	**10,000**
Travel[3]	1,500	**1,500**
TOTAL	29,700	**34,700**

[1]1FTE time slip worker
[2] Lab supplies
[3] In-state travel to orchard plots and packinghouses

CONTINUING REPORT **YEAR 2/3**

Project Title: A biochemical approach to quantifying pear psylla predation in the field

PI: Tom Unruh,
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Cooperators: Dave Horton, Vince Jones, Steve Welter

Funding History:
Year initiated: 2001 ($4,000)

JUSTIFICATION:

A softer, more sustainable pear IPM system requires that pesticide use be minimized to times when it is clearly needed and the pesticides used should be the least disruptive materials that are able to reduce pests to below injury levels. Also, the decision to use insecticides should consider the relative abundance of natural enemies and if they are capable of reducing pest levels. We do not yet have enough understanding to accurately predict when predator abundance is likely to remove the threat of psylla population growth and its concomitant damage. This proposal is designed to help us reach that sort of sophistication for pear IPM.

Many past studies have characterized psylla abundance from a combination of leaf counts and beat tray data and predator abundance from beat trays. The effect of predators on psylla population changes has been inferred from the loose correlations of these relative measures of pest and predator abundance through time. These studies are highly variable and have provide little foundation for management decisions except in the hands of the most experienced and biocontrol friendly pest consultants. Current sampling approaches are inadequate to estimate both predator and psylla abundance. Beat trays are used to sample adult psylla and all mobile predator stages but the relative sampling efficiency on each species and perhaps life stage are likely to differ markedly. These differences may be influenced by the season, tree architecture, and temperature as well as species specific behaviors. While we may know in the laboratory that predator X may eat 25 psylla per day, we do not know how many they eat in the field nor how that may be influenced by prey densities and the availability of other prey or other factors. Hence, spending exceptional effort in calibrating psylla and predator sampling to each other may not solve the problem. A more direct approach is warranted Unfortunately, only a few studies conducted under very restrictive conditions have experimentally estimated actual predation effects on psylla where both pest and natural enemy abundance is known Unruh and Higbee 1994). Furthermore, parasitism of psylla has been estimated in only a few studies, even though, unlike predation, parasitism can be directly and accurately measured by rearing or dissection (Unruh et al. 1994).

Over the last 5 years we have been studying methods to measure if a psylla predator has eaten a psylla using specially derived monoclonal antibodies (Horton et al. 1997). During the last year we have been developing a new method with collaborators in Berkeley which bases gut content analyses on the polymerase chain reaction – detecting the DNA of the prey in the predator gut (Agusti et al. 1999, 2000). Nuria Agusti spent the spring of 2000 in my laboratory (on loan from Steve Welter in Berkeley) and we completed development of 2 useful family of primers for amplification of pear psylla mtDNA (sizes of 75 to 288 bp. Our results suggest that a more accurate picture of frequency of feeding may be developed from this approach compared to monoclonal antibodies. In 2000 we asked for modest support for biochemical reagents to continue these studies. Our results give us reason to

take a more aggressive approach to field determination of predation frequency using molecular methods. Some continuation of objectives as proposed in 2000-1 are presented.

Objectives:

1. Utilize PCR to amplify different lengths of pear psylla DNA and use these to estimate predation rates by gut content analysis of *Deraeocoris* and *Campylomma* in pear orchards.

2. Develop field-based time budgets for *Deraeocoris* and *Campylomma* to measure feeding rates in the field and compare these to molecular estimates

3. Conduct supporting laboratory studies to show diel rhythm of feeding behavior and further support molecular and direct observations in the field.

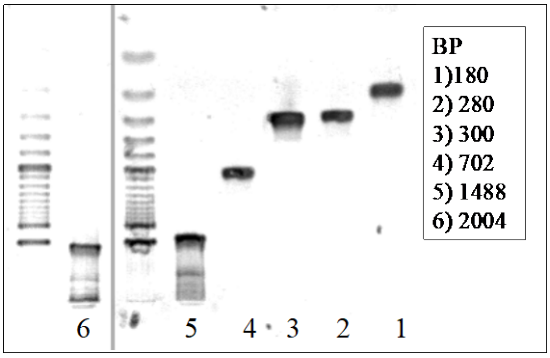
4. Develop primer arrays for other host prey of psylla predators especially mites

Significant findings in 2001

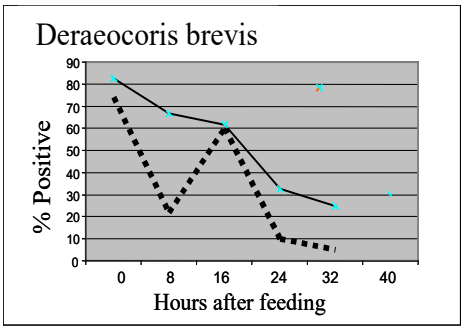
1. Discovered primers to amplify selectively psylla DNA that were larger and are digested more rapidly
2. Completed comparison of Monoclonal antibody and PCR approach
3. Evaluated and optimized a much simpler and inexpensive method to extract predator/psylla DNA.

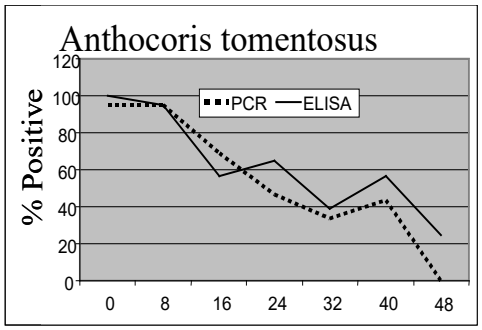
Results and Discussion

Since Dr. Agusti's departure (and with support from WTFRC of $4,000 for supplies) we have continued work and discovered several primers that amplify larger stretches of DNA (right); amplicons; 400-2,000 bp). As amplicons become larger the speed at which they are digested decreases. This means that predation can be detected on shorter and shorter time frames. Ultimately, we hope these time frames will be biologically meaningful. For 2002 we will be working extensively to develop primers to produce amplicons that will be digested within an hour or two. The value of such short retention times is that it approaches a measure of real predation rates.



We have almost completed our comparisons between one monoclonal antibody a 288 bp PCR amplicon. We find PCR and ELISA provide almost identical estimates of digestion rates in *Anthocorus antevolens* and *Deraeocoris brevis* and the retention time of prey signal in the gut of psylla is quite long; more than 24 hr. Assays remain to be done for Deraeocoris where we have considerably more variation in feeding behavior. The variation observed in the data for D. brevisis mostly due to this low sample size.





We have also found that a much simpler and inexpensive extraction method is just as good as techniques used by Agusti and others. Through the winter we will complete comparisons using larger amplicons/primers. We see this as a two-year project at or near the funding level requested for 2002 and are treating this as a new proposal.

Methods:
1. Three orchards with known psylla and predator populations will be sampled roughly monthly through the growing season. Psylla levels will be estimated from leaf samples and predator abundance from beat trays. We will use 4-5 size-dependent PCR primers designed to amplify pear psylla mitochondrial CO-1 DNA. Using beat tray collections at the same times samples are taken we will accumulate and freeze in the field 100 or more individuals of each dominant predator species. Predators will be homogenized intact in Chelex (5%) and all primer sets will be used in separate PCR reactions to detect psylla DNA in each test specimen. Predation rates will be estimated as time since last meal by predators and linear regression will be used to estimate hourly predation rate. Time since feeding studies conducted under objective 3 and in 2001 will be used to estimate approximate feeding rates of insects in the field. We expect that these efforts will be focused on *Campylomma* and *Deraeocoris*, the 2 major predators we have observed in the Pew-EPA and codling moth area-wide projects.

2. Develop field-based time-budgets for *Deraeocoris* and *Campylomma* to validate molecular feeding rates estimates. This is a seldom-used approach because of the labor involved in most predator prey systems, especially when prey and predators are not very abundant. Fortunately, psylla and its predators can be quite abundant. Time budgets will be estimated visually using two complementary approaches. First is the search and note method of looking through the tree and every time a particular predator is observed note what behavior it is engaged in. The second approach, follow and observe, is similar and requires acquiring a predator and following it and recording its behavior until one losses site of it or 15 minutes, whichever is shortest. Both methods yield unambiguous data if interference from the observer with the observed insect's behavior is not a concern and the search and note approach is less succeptible to this bias. Nighttime observations will not be conducted unless day/night activity studies in the lab suggest they are warranted.

3. Conduct supporting laboratory studies to show diel rhythm of feeding behavior that will support molecular and direct observations in the field. Daily patterns of feeding will be evaluated for Campylomma and lacewings in the lab using an existing video system in that can record at all light levels. Dr. Horton is currently rearing *Campylomma*. Lacewings will be purchased from commercial sources. Periodicity will be recorded as the frequency of feeding events at each hour in 24. Observations from at least 10 insects from each species will be used to measure periodicity. PCR primers that we have found that amplify psylla DNA will be evaluated for these 2 predators that we have not critically tested. Both species will be tested fed and unfed and digestion times will be estimated from amplicon sizes of 75, 179, 288, 713, 1231 and 2004 base pairs.

4. Expand primer array to allow testing psylla predators for other prey as well. This is especially important with *Campylomma,* which also feeds voraciously on thrips and mites and where its activity against psylla may be redirected in the presence of abundant alternate prey. We will sequence and align the overlapping CO-I regions of red and two spotted spider mites and identify unique sequence areas for primer design. These will be tested for specificity as done previously for psylla primers. Ultimately this technology may allow us to estimate the time since the last attack for each of a suite of prey attacked by a single predator.

Proposed Schedule of Accomplishments:
Objective 1. Collection of samples for analysis will be completed by August 2002 and analysis of samples will be completed by December 2002.
Objective 2. Field-based time budgets will be collected in June-August of 2002 but it is likely that this work will need to be replicated in 2003.
Objective 3: Comparison between and optimization of primer pairs for different sized amplicons are ongoing and will be completed by spring or early summer. Diel periodicity studies in the lab will begin in January and be completed by summer.
Objective 4. Sequencing and primer design for mites and thrips will be completed by summer or fall of 2002. Field studies related to this and retrospective analysis of samples collected under objective 1 will form part of 2003 efforts.

Literature Review

Quantitative estimation of predation is difficult because, by its very nature, predation leaves little evidence (Hagler et al. 1992). Approaches to measure insect predation broadly include: direct observation, predator enhancement or exclusion, and direct or biochemical estimation of gut contents. Of these only predator enhancement has been used in studies of psylla (Unruh and Higbee 1994) and provided only a weak estimate of predator_prey ratios that may alter pest population trends.

The traditional approach to study the detection of prey proteins in predator guts for predators that suck liquefied prey in field conditions included the detection of prey proteins by analysis of isozymes (Murray & Solomon 1978; Lister et al. 1987; Solomon et al. 1996) or by the development and use of prey_specific Monoclonal Antibodies (MAbs) (Greenstone & Morgan 1989; Symondson & Liddle 1993; Greenstone & Hunt 1993; Symondson & Liddle 1996; Hagler & Naranjo 1996; Greenstone 1996; Agusti et al. 1999; Symondson et al. 1999). However, the uncertainty inherent in, and the cost of generating MABs present practical constraints (Greenstone 1996, Symondson et al. 1999).

A recent alternative strategy is the development of PCR_based techniques for detection and identification of prey DNA in predator guts (Agustí et al. 1999, 2000; Zaidi et al. 1999; Chen et al. 2000; Hoogendoorn & Heimpel 2001). Although previous studies using single copy sequences (Agustí et al. 1999; Agustí et al. 2000) showed satisfactory results, here we explore the use of primers from a sequence that occurs in high copy number in each cell (mitochondrial DNA=mtDNA, ribosomal RNA encoding DNA=rDNA). These sequences lend themselves to faster and more straightforward discovery because of the availability of universal primers that are suitable for many insect taxa (Simon et al 1994, DeSalle et al. 1994) and avoids the cumbersome steps of screening for suitable sequence by Random Amplified Polymorphic DNA (RAPD), which includes cloning and sequencing as done by Augusti et al. (2000). The abundance and membrane protection of mitochondria may also allow detection for longer periods after prey ingestion. The development of molecular markers from multiple_copy sequences, perhaps especially mtDNA, increases the likelihood of successful amplification in gut extracts (Chen et al. 2000). We believe the primer sets produced here will provide useful for quantitative ecological studies of the pear psylla in the field. Several such quantitative studies of insect predation have used serological methods (Hagler and Naranjo, 1994) or isozymes (Lister 1987). Critical to the study of pear psylla in the Western USA would be to provide direct evidence of which species are key predators through the growing season (Unruh et al. 1999).

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Proposed Project Duration: 2 years (2002 and 2003)

Current Year Request: 2002: $28,600

Budget:

A biochemical approach to quantifying pear psylla predation in the field
Tom Unruh

Item	2001	**2002**	2003 [2]
Salaries	–0--	**22,000**[1]	22,000
Benefits	4,000	**6,600**	6,600
Total	4,000	**28,600**	28,600

[1] Partial salary for visiting scientist
[2] We hope that data collected in 2002 will support a successful NRI proposal. Furthermore, predation estimation work in psylla will be a major focus of my work under IFAS in 2003-4. Thus this projected request for 2003 may be significantly reduced.

CONTINUING PROJECT: **YEAR 3/3**

TITLE: Storage behavior and handling of Concorde pear as influenced by harvest maturity.

PROJECT LEADER: Eugene A. Mielke, OSU, MCAREC

COOPERATORS: Paul M. Chen, OSU, MCAREC
Tom Auvil, WTFRC, Wenatchee
Randy Smith, Grower, Cashmere

FUNDING HISTORY:

Year initiated:	1999
Funding in 2001-2002:	$6,000

SIGNIFICANT FINDINGS:

Fruit from Washington and Oregon was used to determine the appropriate harvest maturity standards and storage potential for Concorde pear. Results from the first years, and initial samples from the second year's, research have brought some additional concerns to light. They are: 1) Compared to fruit in the first year of the experiment, fruit in the second year were approximately 2 pounds lower in pressure when the fruit obtained a "mature" appearance on the tree, and fruit pressure declined very little over the 4 week harvest interval. 2) During the first year of the research, after four months of storage, the quality of the fruit stored under CA conditions was not noticeably better than that of fruit stored in air. 3) Internal breakdown occurred in the core area and vascular tissue immediately above the core area in some fruit and became more evident with ripening. 4) Some of the second year harvest samples appear to contain two distinctively different populations of fruit, which seem to behave differently during ripening. and 5) Concorde appears to be able to set fruit parthenocarpically, which may lead to some of the problems described above.

OBJECTIVES:

1. To determine the storage life, chilling requirement, and ripening quality of Concorde pears as influenced by harvest maturity, storage conditions, and production region.

2. To determine the resistence to handling induced scuffing of Concorde pears as influenced by harvest maturity and production region.

PROCEDURES:

Objective 1: To determine the storage life, chilling requirement, and ripening quality of Concorde pears as influenced by harvest maturity, storage conditions, and production region.

Fruit from Cashmere, Hood River, and Lake Chelan was harvested three times in 2000. They were: 1) Onset of commercial CA green d'Anjou harvest; 2) two weeks after the initial harvest; and 3) four weeks after the initial harvest.

In 2000, at each harvest, 16 boxes of fruit were harvested from each location and packed into boxes with poly liners. Eight boxes of fruit were stored in conventional refrigerated storage at -1C and 9 boxes were stored in controlled atmosphere conditions at 0.8% O_2 and 0.0% CO_2. After 2 or 4 months conventional storage (RA), or 4 or 6 months CA storage, three boxes of fruit were transferred to a ripening room at 68F. After day 1, 3, 5, and 7 of ripening at 20C, FF was evaluated. After day 1 and 7, TA, and SSC were evaluated. On day 7 of ripening the dessert quality of the ripened fruit was assessed.

Objective 2: To determine the resistance to handling induced scuffing of Concorde pears as influenced by harvest maturity and production region.

In 2000, following each storage cycle, fruit from each location was used to determine the sensitivity to skin scuffing. The fruit from each sample lot was divided into five lots (fifteen fruit each) and each lot placed on a brush bed (50:50, 0.05 Pec:horsehair brushes) operating at 60 rpm for 30, 60, 120, and 240 seconds. The control consisted of non-scuffed fruit. The fruit was transferred to a ripening room at 20C for 7 days and the degree of scuffing evaluated.

RESULTS AND DISCUSSION:

Fruit stored for 4 months was significantly lower in pressure after all days of ripening (Table 1); however, by day 5 and 7 the differences were very small. Green fruit were significantly lower in pressure than yellow fruit. Soluble solids were lower before and after ripening in green fruit as compared to yellow fruit (Table 2). Soluble solids were not affected by length or type of storage. Total acid declined with length of storage; however, CA conditions partially preserved the total acid content. Harvest maturity did not affect the soluble solids content. Total acid declined with advanced harvest maturity. Harvest maturity did not affect the extractable juice content in unripened fruit (Table 3). Extractable juice content did increase at later harvest dates indicating a lower desert quality. As harvest maturity increased, the difference between day 1 and day 7 extractable juice content decreased. Green fruit exhibited a greater difference between day 1 and day 7 extractable juice than yellow fruit.

Texture and flavor were best in fruit harvested 2 weeks after the onset of commercial d'Anjou harvest (Table 3). Texture was poorer in fruit stored under CA conditions. This was possibly due to the fact the low oxygen condition (0.8 % O_2 and 0 % CO_2) was too harsh for the cultivar. This is suggested by the large amount of senescent scald found in the CA samples. Flavor was best in fruit from the second harvest date. Green fruit exhibited less flavor that yellow fruit. Astringency was only noted in fruit from the first harvest date, and was only present in fruit stored for four or more months.

The percentage of rot was not affected by either location or harvest maturity (Table 4). Rot did increase with the length of storage. The percentage of scald and scald index was reduced with later harvest maturity. Both the percentage of fruit affected with pithy brown core symptoms and the pithy brown core index increased with increased harvest maturity and length of storage. It is interesting to note the presence of pithy brown core in the fruit stored in air for four months. Pithy brown core is normally thought to be caused by high CO_2 injury, which would not have occurred in the air storage conditions. This condition may be due to boron deficiencies as noted in other crops. Flesh and core browning and senescent breakdown increased with harvest maturity and length of storage (Table 5). Green fruit were less susceptible to core and flesh browning than yellow fruit. Both core and flesh browning have been attributed to boron deficiency in Conference, which is one of Concorde's parents.

The susceptibility of the fruit to scuffing injury was increased with harvest maturity, length of storage, and the length of time on the brushes (Table 6). Injury was compounded by later harvest, longer storage length, and increased brush exposure time. There was no significant difference between Oregon and Washington fruit.

CONCLUSIONS:

Concorde exhibits a major problem in non-uniform maturity. This is expressed in the presence of green and yellow fruit following storage. The green fruit is softer than yellow fruit and

has lower flavor. This makes the proper determination of harvest maturity extremely difficult. The fruit appear to have a limited storage life, and CA storage (under the conditions used) did not appreciably extend storage life. Fruit harvested at a later date had better texture and did not exhibit astringency following 4 months of air storage. Later harvested fruit was more prone to storage disorders. Fruit stored under CA exhibited a high level of decay and a "senescent scald-like" disorder.

Appropriate harvest maturity and storage length cannot be reliably determined until the problem of non-uniformity of fruit maturity can be solved, or until it is possible to separate two populations of fruit at harvest. It appears that it might be possible to do this after one or two months of storage with a color sorter. As the green and yellow fruit differ in both pressure and soluble solids, it may be possible to separate the two populations by online pressure and soluble solid sorters when available.

Table 1. Main effects of location, color, harvest maturity, and storage length and type on flesh firmness of Concorde pears during seven days of ripening at 68° F.

			Flesh Firmness (lb)			
Location	Harvest	Storage	Day 1	Day 3	Day 5	Day 7
HR1	-	-	8.5 b[z]	7.1 b	4.4 b	3.2 b
HR2	-	-	9.1 a	7.8 a	5.0 a	3.7 a
WA-Grn	-	-	8.1 c	6.0 c	3.1 c	2.3 c
WA-Yel	-	-	9.4 a	7.9 a	5.1 a	3.3 b
-	1	-	9.2 a	7.5 a	4.3 b	3.3 a
-	2	-	9.0 a	7.3 ab	4.6 a	3.2 ab
-	3	-	8.2 b	6.9 b	4.3 b	3.0 b
-	-	Air 2	9.4 a	7.6 a	4.6 a	2.8 c
-	-	Air 4	9.0 b	6.8 b	4.2 b	3.3 a
-	-	CA 4	9.2 ab	na	na	3.1 b
-	-	CA 6	7.6 c	na	na	3.4 a

[z] Within a column and section, means with the same letter are not significantly different at the 5 % level.

Table 2. Main effects of location, color, harvest maturity, and storage length and type on the soluble solid and total acid content of Concorde pears before and after seven days of ripening at 68° F.

			Unripened		Ripened	
Location	Harvest	Storage	Soluble Solids (%)	Total Acid (g/100ml)	Soluble Solids (%)	Total Acid (g/100 ml)
HR1	-	-	15.8 a[z]	1.09 b	16.0 a	1.15 b
HR2	-	-	16.0 a	1.35 a	16.9 a	1.30 a
WA-Grn	-	-	13.3 b	0.89 c	13.3 c	1.08 b
WA-Yel	-	-	15.2 a	0.85 c	14.4 b	1.00 b
-	1	-	14.8 a	1.16 a	14.8 a	1.25 a
-	2	-	15.2 a	1.03 b	15.1 a	1.13 b
-	3	-	15.2 a	0.95 b	14.9 a	1.01 c
-	-	Air 2	15.5 a	1.29 a	15.2 a	1.32 a
-	-	Air 4	15.1 a	0.93 c	14.8 a	1.06 b
-	-	CA 4	14.8 a	0.98 b	14.9 a	1.07 b
-	-	CA 6	15.8 a	1.09 b	16.0 a	1.15 b

[z] Within a column and section, means with the same letter are not significantly different at the 5% level.

Table 3. Main effects of location, color, harvest maturity, and storage length and type on the extractable juice content of Concorde pears before and after seven days ripening at 68° F, and fruit texture, flavor, and astringency following seven days of ripening at 68° F.

			Extractable Juice (ml)				
Location	Harvest	Storage	Unripened	Ripened	Texture	Flavor	Astringency
HR1	-	-	70.0 c[z]	67.2 a	6.8 b	7.2a	0.18 a
HR2	-	-	69.5 c	67.0 a	6.7 b	7.2 a	0.06 b
WA-Grn	-	-	73.0 a	67.3 a	7.6 a	6.0 b	0.08 b
WA-Yel	-	-	71.4 b	68.0 a	7.2 a	7.5 a	0.04 c
-	1	-	70.6 a	65.8 c	6.2 c	7.2 b	0.27 a
-	2	-	71.2 a	67.5 b	8.0 a	7.3 a	0.00 b
-	3	-	71.1 a	69.0 a	6.9 b	6.4 c	0.00 b
-	-	Air 2	71.1 ab	66.8 b	7.3 b	8.1 a	0.00 d
-	-	Air 4	71.7 a	69.2 a	7.7 a	7.6 b	0.24 a
-	-	CA 4	70.6 b	66.9 b	7.0 c	6.6 c	0.04 c
-	-	CA 6	70.0 c	67.2 a	6.1 d	5.6 d	0.08 b

[z] Within a column and section, means with the same letter are not significantly different at the 5 % level.

Table 4. Main effects of location, color, harvest maturity, and storage length and type on the percent rot, percent scald, scald index, percent Pithy Brown Core, and Pithy Brown Core index on Concorde pears following seven days of ripening at 68° F.

Location	Harvest	Storage	% Rot	% Scald	Scald Index	% Pithy Brown Core	Pithy Brown Core Index
HR1	-	-	7.7 a[z]	36.2 b	123 b	24.2 bc	58 bc
HR2	-	-	9.7 a	42.7 a	159 a	31.6 b	81 b
WA-Grn	-	-	7.2 a	40.9 a	160 b	16.9 c	43 c
WA-Yel	-	-	11.4 a	44.3 a	171 a	45.8 a	112 a
-	1	-	9.4 a	43.6 a	172 a	25.5 b	61 b
-	2	-	9.3 a	42.0 a	160 a	26.2 b	63 b
-	3	-	8.4 a	37.5 b	129 b	37.1 a	96 a
-	-	Air 2	0.0 c	0.0 c	0 c	0.0 c	0 c
-	-	Air 4	13.0 b	1.3 c	1 c	34.9 b	87 b
-	-	CA 4	2.9 c	83.9 a	331 a	37.5 b	76 b
-	-	CA 6	20.0 a	79.0 b	283 b	46.1 a	131 a

[z] Within a column and section, means with the same letter are not significantly different at the 5 % level.

Table 5. Main effects of location, color, harvest maturity, and storage length and type on the percent flesh browning, flesh browning index, percent core browning, core browning index, and percent senescent breakdown on Concorde pears following seven days of ripening at 68° F.

Location	Harvest	Storage	% Flesh Browning	Flesh Browning Index	% Core Browning	Core Browning Index	% Senescent Breakdown
HR1	-	-	29.7 c[z]	64 c	24.9 c	81 c	2.2 a
HR2	-	-	45.1 b	119 b	36.4 b	121 b	4.8 a
WA-Grn	-	-	26.8 c	65 c	21.0 c	71 c	4.3 a
WA-Yel	-	-	58.6 a	160 a	53.1 a	200 a	5.4 a
-	1	-	34.6 b	78.8 b	27.2 b	84 b	3.0 a
-	2	-	37.1 b	84.0 b	29.4 b	94 b	3.0 a
-	3	-	48.5 a	143 a	44.9 a	178 a	6.6 a
-	-	Air 2	2.1 c	3 b	1.5 c	3 b	0.0 b
-	-	Air 4	53.7 a	139 a	41.8 b	147 a	6.0 a
-	-	CA 4	44.9 b	123 a	40.0 b	151 a	3.2 ab
-	-	CA 6	59.6 a	143 a	52.0 a	172 a	7.5 a

[z] Within a column and section, means with the same letter are not significantly different at the 5 % level.

Table 6. Main effects of location, harvest maturity, storage length and type, and length of scuffing on injury following seven days of ripening at 68° F.

Harvest	Storage	Time (sec)	Oregon	Washington
1	-	-	1.10 b[z]	1.09 c
2	-	-	1.29 a	1.27 b
3	-	-	1.34 a	1.39 a
-	Air 2	-	0.71 c	0.75 c
-	Air 4	-	1.21 c	1.33 b
-	CA 4	-	1.55 a	1.42 ab
-	CA 6	-	1.49 a	1.51 a
-	-	0	1.10 c	1.12 c
-	-	30	1.17 bc	1.18 bc
-	-	60	1.18 bc	1.25 b
-	-	120	1.26 b	1.27 c
-	-	240	1.50 a	1.45 a

[z] Within a column and section, means with the same letter are not significantly different at the 5% level.

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FINAL REPORT
WTFRC Project # PR-01-103 **WSU Project #** 3298

Project title: Bioregulators for management of vegetative growth and fruit quality in pear

PI: Don C. Elfving, Horticulturist
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Accomplishments:
Nineteen trials with bioregulators were established on pear trees between 1999 and 2001; all trials were located in grower orchards. Most of these trials were designed to evaluate the growth, flowering and fruiting responses of vigorous pear trees to various strategies for timing and concentration of Apogee application to entire trees or to the tops of mature trees. Other trials examined the potential of Apogee to affect harvest maturity and quality of 'Bartlett' pear and the effects of cytokinins and gibberellic acid on pear fruit size and shape.

Results:
- Apogee applications in spring reduced vegetative growth temporarily but often resulted in production of a second flush of growth.
- Control of this second growth flush with Apogee is costly and difficult.
- Apogee could induce a second growth flush with as few as a single spring application.
- In rare cases, the vigor of the second growth flush exceeded that of untreated trees.
- When pears make a second growth flush, additional lateral shoots may be produced in addition to any renewed extension of previously active shoot tips.
- Apogee can be used on young, vigorous pear trees to induce a second growth flush and thereby increase the production of weaker lateral branches, which can be retained in the canopy architecture to provide sites for fruiting.
- On young, vigorous pear trees of the cultivars 'Starkrimson' and 'Anjou', successful induction of a second growth flush with Apogee can result in more shoot growth than in untreated trees but with more of that shoot growth in a larger number of weaker shoots that are more desirable for canopy formation.
- Apogee has been applied successfully to control vigorous shoot growth in the tops of mature 'Anjou' and 'Bartlett' pear trees.
- Where Apogee reduced vegetative vigor in the tops of mature trees, the amount of pruning required to remove unwanted vegetative growth was substantially reduced.
- Apogee did not improve flowering in 'Bartlett' or 'Anjou' pear the next year regardless of its effect on vegetative vigor in the year of treatment.
- Apogee reduced the return bloom in 'Bosc' pear, regardless of whether the trees had already begun cropping or were initiating flowers for the first time.
- Spring-applied Apogee consistently reduced pear fruit size at harvest.
- The reduction in pear fruit size at harvest did not result from any change in fruit set on Apogee-treated trees nor did it involve any change in fruit shape.
- Apogee-induced reduction in pear fruit size appeared to depend on the number of applications and the concentration of Apogee in sprays applied during the first four weeks after bloom.
- Increased number of Apogee applications and/or higher Apogee concentrations appeared to have a greater effect on reducing fruit size.
- Spring Apogee treatment had no effect on the harvest or postharvest behavior of 'Anjou' pear.

- Spring Apogee treatments were inconsistent in their effects on ‘Bartlett’ pear maturity and postharvest behavior, thus not representing an effective option for ‘Bartlett’ harvest scheduling or postharvest management.
- Cytokinin and gibberellic acid applications were unsuccessful in increasing pear fruit size over untreated fruit but did increase the length/diameter ratio of treated ‘Anjou’ fruit to the point of being unrecognizable, not an advantage for marketing.
- Apogee did not produce interactive effects with rootstock on shoot growth, flowering or fruiting phenomena in pear trees.

Summary:
Apogee produced a number of growth-based responses in pear trees, but many of those responses were not deemed to be useful by the labeling company, BASF. As a result of findings produced by this project and other findings as well, BASF removed the registration for Apogee on pears in late 2001.

FINAL REPORT

TITLE: Magnitude of the Residue Evaluation for Applaud® 70WP on Pears

PI: Vincent R. Hebert, Residue Laboratory Director,
Food and Environmental Quality Laboratory, WSU TriCities

COLLABORATORS: Doug Walsh, Washington State IR-4 Liaison Representative,
WSU Prosser, WA

Chuck Mourer and Matt Hengel
IR-4 Western Regional Laboratory, UC Davis, CA

OBJECTIVES:

The USDA Interregional–4 (IR-4) Minor Crop Project has received a petition from Washington for securing a tolerance for Applaud 70WP in pear production. The active ingredient in this formulation is the insect growth regulator, buprofenzin. This formulation is expected to be efficacious against pear psylla without appreciably altering the complex of natural enemies of this pest. This request has been given an "A" priority by IR-4 and fieldwork was completed in 2001. WSU's Food and Environmental Quality Laboratory (FEQL) was asked to provide residue analysis for buprofenzin in pears. The IR-4 tolerance submission for this safer material should receive "fast track" registration attention by EPA since it is considered a reduced risk pesticide. Funding from the Pear Review Board was requested by FEQL to provide quality assurance and technical support to complete the analytical portion of this study in a timely manner for "fast track" registration purposes. Proposal objectives were stated as follows:

1. Analyze total residues of buprofezin (i.e., active ingredient of Applaud® 70WP) in/on pears collected from *Magnitude of the Residue* field trials conducted according to commercial application practices.
2. Complete residue analyses and reporting within 6 months after receiving field samples for timely registration of this material for use in pesticide resistance management practices.
3. Complete all phases of analytical work by February 2002.
4. Work with IR-4 to have a reduced risk registration package submitted to EPA in 2002.

All stated objectives in the FY 2001 proposal will be completed on time. Residue analyses were completed within 6 months of sample receipt (objective 2). The finalized/audited analytical report will be submitted to IR-4 by February 2002 (objective 3), and the P.I. is coordinating with IR-4 to help guarantee the 2002 delivery of pear residue data to the EPA for an expedited registration as a "reduced risk pesticide" (objective 4).

SIGNIFICANT FINDINGS:

Eight field locations representative of major pear production in the U.S. (three in the PNW) were treated twice with Applaud 70 WP at a maximum use rate (1.58 lb/A/app.) with a minimum 14-day pre-harvest interval. Two plots were involved with each site: a treated and non-treated plot. Duplicate samples were taken from each of the two plots (i.e., 2 duplicates x 2 plots x 8 locations, or 32 total samples). The analytical residue method used in this study was derived from a method provided by AgrEvo, RAM number: BF/10/97: *"An Analytical Method for the Determination of Residues of Buprofezin at Estimated Tolerance Levels in Almonds, Cottonseed, Citrus (Lemons), and Grapes by Gas Chromatography Using Nitrogen Phosphorus Detection."* Modifications to the above method for the specific requirements of analyzing buprofezin residues on pears are stated in the modified working method: "*Working Method for Determination of Residues of Buprofezin in Pears*

by Gas Chromatography Using Nitrogen Phosphorus Detection (FEQL Project No.: FEQL-0101) as part of the residue report. Over the course of analyses, ample quality control samples (calibration standards, blanks, fortified and non-treated samples) were assessed to guarantee the integrity and precision of analysis. The above field and analytical work was performed under strict conformance to 40CFR Part 160 Good Laboratory Practice Standards. An independent Quality Assurance Unit inspected critical phases during the analyses and audited all data and analytical report findings.

The method validation set, together with concurrent quality control samples (fortification recoveries) ran during analyses indicate the working method accurately reflects encountered buprofezin residues from a two application program conducted at 1.58 lb. a.i./A/app. with a minimum 14-day PHI. Validation, recovery and residue results from the eight treatment plots were as follows:

QUALITY CONTROL

	Percent Recoveries	**Average**	**Standard Dev.**
Validation Range %	84-118	101	9
Recovery Range %	88-122	101	10

RESIDUE ANALYSIS

Sample location	**Untreated Control (in ppm)**	**Duplicate Treated Samples (in ppm)**
California trial	<0.05	0.31, 0.40
California trial	<0.05	0.57, 0.60
California trial	<0.05	0.81, 1.11
Washington trial	<0.05	0.68, 0.60
Washington trial	<0.05	1.31, 1.12
Idaho trial	<0.05	2.70, 3.64
Colorado trial	<0.05	1.09, 0.71
New Jersey trial	<0.05	0.71, 0.86

The maximum residue encountered was from the Idaho trial at 3.6 ppm. The results suggest that IR-4 will most likely propose a residue tolerance of 5 ppm according to the two application 1.6 lb/A/ app., 14-day PHI use pattern to the EPA for registration approval.

DELIVERABLES:

Exact copies of the original raw data, protocol, correspondence logs, and all relevant information for the GLP study titled: “Magnitude of the Residue Evaluation for Applaud® 70WP on Pears”, PR. No. 07518, among with a certified copy of the signed analytical summary report will be maintained in the archives at FEQL. The original protocol, data, analytical summary report, and relevant information for the construction of this study will be transferred to IR-4 national headquarters in Rutgers, N.J. A certified true copy of the ca. 60-page GLP final residue report will be provided to the Pear Review Board through the Washington State Tree Fruit Research Commission in February 2002.

FINAL REPORT
PROJECT NO: PR-01-93

TITLE: The Wenatchee Valley Pear IPM Project

PERSONNEL: Ted Alway, TC Alway Consulting, Peshastin, WA

SIGNIFICANT FINDINGS:

- Pear psylla populations were higher in the soft blocks in the first year, but declined in subsequent years to levels similar to the conventional blocks.
- Grape mealybug and spider mites were lesser problems in the soft blocks. Pear rust mite increased in many soft blocks by the third year. Other pests were at similar levels between the two treatment regimes.
- Natural enemies were far higher in the soft blocks; the principal ones found were *Deraeocoris brevis, Campylomma verbasci,* lacewings, earwigs and *Trechnites sp.*
- Fruit marking was higher in the first year in the soft blocks, due to pear psylla, but damage levels were similar in later years.
- Pest control costs averaged $150-$200/ac less each year in the soft blocks.
- Proximity to native habitat is important to pear orchards trying to attract and retain natural enemies.
- The expansion of soft pear pest management programs is limited by the lack of critical numbers for pests and natural enemies, the limited personnel to collect and interpret monitoring data, and the greater risk of fruit marking.

JUSTIFICATION:

The Wenatchee Valley Pear IPM Project (WVPP) investigated whether more cost-effective pear pest management programs could be implemented by the increased use of biological control. Several factors encouraged the development of this project. Pest control costs were rising steeply, and Wenatchee Valley growers were spending more than most of their western North American counterparts. Pest populations and damage were as serious as ever. Regulations were limiting or eliminating the use of many pesticides. At the same time, several new pesticides and pest control methods were becoming available but were almost untested in the area. Biological control was an important, and cost-saving, part of pest management programs in other western pear districts but was little used in the more pesticide-intensive programs of the Wenatchee Valley.

OBJECTIVES:

1. Develop pear pest management programs with extensive use of biological control of key pests.
2. Demonstrate the successful use of softer pear pest management programs and identify limitations to further adoption.

METHODS:

Fifteen growers provided pear blocks for the project in Year 1; one grower (#10) sold the orchard after Year 2, and three new blocks were added in 2001. Anjou pear was the cultivar sampled in each orchard. This variety is quite susceptible to pear psylla and spider mites, two of the main pests in the Valley, and provided a good test for soft programs. The blocks were located throughout the Wenatchee Valley, from the western edge of Wenatchee to just east of Leavenworth. They varied considerably in their surroundings (native vegetation vs. orchard, narrow canyon vs. extensive farmed area). Details on the WVPP pear blocks, as well as spray records and extensive monitoring data

summaries, are found in the WVPP annual reports produced each year. Table 1 at the end of this report presents three-year summaries of key data from the project.
There was a better opportunity to develop biological control in these blocks than in many Wenatchee Valley orchards for two reasons: 1) the growers who volunteered were predisposed to "push the limits" in these blocks to let natural enemy numbers build, and 2) many of the orchards were adjacent to native habitats that served as a source of natural enemies.

Every block was sampled weekly beginning in mid March, before the first sprays were applied, until after harvest. The sample methods varied with the stage of development of the pests and crop, and were based upon the methods outlined in Orchard Pest Monitoring Guide for Pears (published by the Good Fruit Grower, 1999). The sample data from each visit was sent the same day to the grower and associated fieldmen. This prompt turnaround time allowed the grower to closely monitor the development of pests and natural enemies and use the information in making pest control decisions. A monthly newsletter was sent to all participants, presenting information on pests, natural enemies, pest control options and WVPP developments. Regular lunch meetings were held with consultants to discuss findings and control options.

No pest control recommendations were provided by the WVPP. Information was provided on less-disruptive pest control options that could conserve natural enemies. The growers managed their pest control programs using the information provided by the WVPP and the advice of their consultant(s). All growers were interested in encouraging the development of more biological control in their orchards and balanced this with the risk of pest-caused fruit damage. Consequently, no two blocks followed the same spray program. The fifteen blocks were essentially in two categories:

1. "Conventional" blocks used broad-spectrum insecticides before and after bloom for pear psylla and grape mealybug control. These insecticides included AgriMek, Pyramite, pyrethroids (Asana, Baythroid), neonicotinyls (Provado, Actara) and organophosphates (Lorsban, Diazinon, Guthion, Imidan).
2. "Soft" blocks used none of the above materials (with a few exceptions). For psylla control sprays, these growers mostly relied upon pre-bloom Surround, Esteem, azadirachtin and foliar oil.

Over the three years of the project the distinction between programs became blurred as the growers and consultants adapted to what was learned and sought the most economical approach. Conventional growers increasingly used both Surround and foliar oil sprays, and some soft growers used post bloom OP sprays. There was a pest management transition among the fifteen original pear blocks. By Year 3, two of the original seven conventional blocks became soft and two of the original eight soft blocks became organic, increasing the total under organic management to four.

RESULTS AND DISCUSSION:

Pests

Wenatchee Valley pear growers regularly contend with pear psylla and twospotted spider mites, and grape mealybug is a serious and increasing problem for many. Codling moth, leafrollers, pear rust mite, stink bugs and boxelder bugs can and do cause problems as well. The status of most of these pests changes with soft pest management programs.

Pear psylla causes more overall losses each year, through downgraded and culled fruit, weakened trees and discouraged pickers, than any other pest in the Valley. The WVPP soft programs dropped the main psyllicides used by most area growers and relied instead upon oil, tree washing and natural enemies for post bloom control of psylla. In Year 1, almost all soft blocks had high summer psylla populations and suffered extensive fruit marking. Psylla predators and parasites increased their

numbers and, together with the use of selective insecticides, generally provided good psylla control in Years 2 and 3, equal to the conventional blocks. Biological control alone will not control psylla adequately; supplemental sprays are needed each year, with the extent of sprays determined by psylla and natural enemy populations each year.

Prebloom control of psylla is important in any management program, and even more so in soft programs in which the summer options for selective sprays are essentially limited to foliar oils and tree washing. Beating tray counts of psylla adults should be below 1.0/tray by popcorn timing, even in soft blocks with a good bio control history; we've not yet been concerned about a lack of food for predators! Adult numbers can be reduced to very low levels without disrupting bio control by use of just Surround, oil and sulfur, with Thiodan a safe option for additional control.

Psylla nymphs appear on shoot leaves beginning in mid to late June; summer controls must focus on keeping this and subsequent generations below critical levels. Fruit marking was acceptably low in WVPP blocks in which psylla nymphs on top shoot leaves did not exceed 1.0/leaf for more than one week in the late June to early August period, and in blocks where the average count of psylla nymphs per top shoot leaf in July was 0.5 or less. We also found that higher nymph populations and honeydew amounts could develop in mid August or later with little risk of fruit marking on Anjous (although at a risk of driving off pickers!) A late season psylla population can maintain natural enemies, with a carryover benefit to the next spring. Once psylla natural enemies were established, good control was achieved in the soft blocks; the least psylla marking each year came from two organic blocks as well as two conventional blocks. Psylla problems in soft blocks after the transition year (Year 1) were related to poor prebloom control, ineffective sprays (fish oil) or disruptive sprays (summer Surround and possibly azadirachtin).

Grape mealybug has increased its range and severity in the Wenatchee Valley over the past ten years. It is found in other western pear regions but is rarely a pest. Repeated and expensive sprays of disruptive materials are used for control in the Valley. In the WVPP soft blocks, mealybug populations either declined or remained low, and no sprays were applied for mealybug control. In contrast, the conventional neighbors to many of the soft blocks regularly sprayed for mealybug control. This pest may be induced by the use of broad-spectrum insecticides, so growers with a new or low mealybug population may be best off to not begin treatments for it. Orchards with high mealybug populations may not be able to transition to a soft program without extensive damage for one or more years. In only one of the two WVPP soft blocks with high populations in 1999 have mealybugs ceased to be a problem; disruptive summer sprays (Surround and azadirachtin) in the other have harmed natural enemy populations and limited bio control.

Twospotted spider mites can cause extensive leaf damage and drop on Anjou pear trees. Treatment thresholds as low as 1.0/leaf have been suggested. In the WVPP soft blocks very few miticides were applied, and none other than oil after Year 1. Spider mites failed to build up, even in the absence of any sprays, in most soft blocks. Where control was needed, one or two sprays of foliar oil were effective. This was in contrast to the higher populations that were often found in the conventional blocks and required miticide applications. Use of the pesticide Provado was shown in the WVPP and elsewhere to lead to higher mite populations. It should not be used in soft programs and other neonicotinyls, such as Actara, must be evaluated for their potential to cause the same problem. Biological control undoubtedly contributed to spider mite control. Mite predators were found infrequently on leaf or tray samples, not surprising considering the low mite populations; much of the mite bio control may occur before they reach the tree canopy, on the trunk or in the cover crop.

Pear rust mite is usually well controlled by miticides in conventional programs and rarely causes fruit damage. Rust mites increased in the WVPP soft blocks and caused fruit marking in several blocks by

the third year. Pear growers in British Columbia who moved into soft programs experienced the same problem over the same time period. Additional miticides are needed in many soft blocks to reduce rust mite numbers. Prebloom sulfur and oil are not enough. Prebloom Thiodan has suppressed rust mites well and soft growers will need to consider other options, including post harvest sulfur and low rates of Carzol and AgriMek.

Codling moth is usually not a serious pest for Wenatchee Valley pear growers, but regional populations have grown with an increase in neglected orchards and reduced control programs. Most WVPP growers used only mating disruption for codling moth control. The common sprays for codling moth control (OPs) are harmful to many natural enemies and disrupt biological control. New insect growth regulators (Esteem and Intrepid) provide codling moth control with little or no disruption. Intrepid looks particularly good for codling moth and leafroller control, and can be used alone or with mating disruption. Codling moth can be controlled with soft materials but only if consistently kept under control. Two soft growers developed serious codling moth problems. Grower #4 had a moderate population of CM that became much worse when a spring frost almost, but not quite, eliminated his crop and he abandoned CM sprays. Grower #6 had a dirty neighbor that infested his block. In each case, the grower responded by increasing the rate of mating disruption dispensers to close to 400/acre and applied two Guthion sprays. Codling moth was brought under control and, although some natural enemies were reduced, bio control of psylla was not seriously disrupted.

Leafrollers were trapped in all blocks. Obliquebanded leafroller came to be the dominant species in most WVPP blocks, and pandemis leafroller was widespread. European leafroller (*Archips rosanus*) was found in a number of orchards, particularly in side canyons. Like codling moth, leafrollers can be kept below damaging levels in soft programs if consistent attention is paid to control. Leafroller damage tended to increase in a number of soft blocks in the second year. Well-timed Bt sprays reduced populations and damage the next year. Esteem and Intrepid are effective, non-disruptive leafroller insecticides. The soft blocks that applied petal fall Esteem for psylla had lower leafroller catches and lower fruit damage each year, with no other sprays applied for leafrollers.

Stink bugs and boxelder bugs caused increased damage in many WVPP orchards in Years 2 and 3. This problem was associated with the nearby native vegetation and not with the spray program, and occurred mostly in the outer rows of the block. The extent of damage by stink bugs and boxelder bugs probably reflects the size of their populations in the nearby wild lands, determined by factors beyond the control of the orchardist.

Natural Enemies

A diverse complex of predators and parasites developed in the WVPP soft blocks, with most of those identified feeding on pear psylla. The conventional blocks had far fewer types of natural enemies, and much lower numbers of those that were found. Over 20 different types of natural enemies were found. The five identified as being most effective and/or most abundant were deraeocoris (*Deraeocoris brevis)*, campylomma *(Campylomma verbasci)*, lacewings, earwigs and *Trechnites sp.,* a parasitic wasp.

A diverse complex of natural enemies is needed for the most effective biological control. The diversity better allows the various natural enemies to "cover for each other"; when one species is absent or at low numbers during a particular season or time of year, the others may fill the gap. Some species are active early in the year (deraeocoris, snakeflies), while others don't appear until after bloom (campylomma, earwigs), or build to significant numbers until later in the summer (lacewings). Some are particularly sensitive to many pesticides (Trechnites) while others show greater tolerance (campylomma). Each soft block differed in the types, numbers and proportions of natural enemies

found. Natural enemy populations are influenced by many factors including food available (e.g. psylla, mealybugs), sprays applied, weather, overwintering hosts and sites, and more.

The vegetation in the habitats outside the orchard plays an important part in establishing bio control in soft blocks. Wild lands serve as refugia for many natural enemies and may have plants bearing alternate hosts for important predators or parasites. Ponderosa pine often is infested with a scale insect that deraeocoris will feed on in the winter. Bitterbrush has a psyllid that several predators will feed on until June when the psyllid matures, forcing the predators to move on (and into the orchard, we hope!) Pear blocks that are isolated from native habitat may be slower to establish an effective complex of natural enemies. The geography of the Wenatchee Valley puts many orchards close to wild lands and provides a potential advantage for many blocks.

Chief among the psylla predators were two hemipterans (true bugs): deraeocoris and campylomma. "Derries" overwinter in or near orchards and were among the first to be found each year. They reached their highest levels in the soft blocks in August of the first year. "Campies" were the more abundant of the two in most blocks in Years 2 and 3. They overwinter as eggs under the bark of young wood in fruit trees, and emerge each spring during or soon after bloom. High campy populations in a block in late summer are strongly associated with high numbers the next spring. Campies were present in very high numbers in several soft blocks (>2 per tray) but fruit marking by campy was never seen, although a characteristic feeding damage to shoot tips was easily found.

Our observations and those of pear IPM consultants in the Okanagan of British Columbia suggest that significant bio control of psylla is taking place if counts of these predators, alone or in combination, reach 0.5/tray. When significant numbers of predators are present, psylla populations increase more slowly, if at all; the grower in these cases can continue to monitor without fear of a population explosion and still respond in a timely manner if needed. We often saw rapid growth in psylla numbers in conventional blocks with few natural enemies, requiring the grower to respond rapidly to prevent damage.

Lacewings are predators of many insects, including psylla and mealybugs. Brown lacewings were the most common types found in WVPP pear blocks, although green lacewing adults were found in high numbers in some blocks in late summer. Lacewings tended to build up in late July and August, when the larvae were most common on trays.

Trechnites is a parasitic wasp that exclusively attacks psylla. They are quite sensitive to many pesticides, and in 1999 were not identified in the soft blocks until August. They have many generations each year, first appearing close to bloom when they emerge from the parasitized psylla nymphs they overwintered in. Trechnites were counted in all soft blocks by August 2000 and again in 2001. Counts of 0.5-1.0 adults/tray were common. One blocks had over 20/tray at petal fall, and a sample of 12 psylla nymphs showed 100% to be parasitized.

Earwigs are very active predators of many insects, and investigations have shown them to be among the best predators of psylla in the summer. They are primarily active at night and pass the day in protected locations on the tree trunk and ground. Beating tray samples do not accurately reflect earwig population size so we monitored them with earwig "condos", rolls of corrugated cardboard placed inside PVC pipe. Summer counts in the soft blocks were consistently three to six times higher than those in conventional blocks.

Pesticides
Pesticide use determines whether a pear block is "soft", that is, natural enemies are conserved and biological control contributes significantly to pest control. Most pesticides are not inherently "soft" or "hard". The impact of pesticides on natural enemies, or "selectivity", is determined by several factors, among them the rate used and the application timing relative to natural enemy and pest presence. For example, Thiodan is harmful to many psylla predators but its use at delayed dormant timing, to reduce psylla adult numbers, occurs before most of the key predators are active in the orchard. A well-established natural enemy complex has some resiliency and may withstand limited use of some broad-spectrum insecticides, as shown by the use of Guthion sprays in two soft blocks. Pesticides are developed for their effect on pests and information on their impact on natural enemies usually comes later, if at all. The many new pesticides that are now or becoming available (insect growth regulators, neonicotinyls, botanicals, particle films and more) need to be evaluated for their impact on predators and parasites. Based on WVPP experiences, comments can be made on a number of pesticides used in soft pear pest control programs.

Surround- this material is quite effective before bloom at reducing psylla adult counts and egg lay. Coverage is very important, with multiple applications best as buds develop. No advantage was seen with rates above 50#/acre. Post bloom use reduced counts of many natural enemies, provided little control of psylla and led to high spider mite populations.

Horticultural mineral oil- the use of oil applied in the post bloom period has increased dramatically in the Wenatchee Valley over the past three to five years. Soft and organic growers now rely more than ever on oil for post bloom psylla and mite control. Many conventional growers apply oil, often at a 1% rate, with other foliar insecticides. An average of over six gallons per acre of oil, in at least five sprays, was applied to the WVPP soft blocks from popcorn on in 2001. No fruit or leaf marking was observed in these blocks in 2001. To minimize risk, precautions were followed with oil use including: a) don't exceed a 1-1.25% mix, b) adjust volume to spray to wet, not to drip, c) maintain a two week interval between sprays, d) don't apply at temperatures above 85F. Concerns remain with the possible weakening of fruit spurs and reduction of tree vigor with multiple oil applications over several years.

Esteem- this insect growth regulator was used by most of the non-organic soft growers, applied at popcorn and petal fall. No effect on the key natural enemies was noted. Applied for psylla control, it also controlled San Jose scale and can provide some control of leafrollers and codling moth.

Mating disruption- this pest control method can provide or at least help with control of codling moth. Its use has allowed pear growers with low codling moth populations to reduce or eliminate using organophosphate cover sprays that disrupt bio control. The cost of mating disruption may not be justified in blocks where two or less covers are needed unless a soft program is the objective. New, selective and more effective insecticides, like Intrepid, can supplement or replace mating disruption.

Azadirachtin- this botanical insecticide was used in several formulations by WVPP growers. Trials in WVPP blocks showed it may have as much impact on several key natural enemies as psylla. Organically approved materials, such as azadirachtin, also need to be evaluated for selectivity for predators and parasites as well as efficacy on pests.

Tree washes- these materials were applied to wash small psylla nymphs and honeydew from the leaves. The most common material used was inexpensive laundry detergent without bleach, applied at 0.75-1.0 #/100gallons. Psylla numbers were not reduced much, if at all, by these sprays but the rate of increase was slowed. No reduction of spider mites or psylla predators was observed. High water volume is critical to the success of this approach; 500 to 600 gpa is probably a minimum for summer applications on full sized pear trees.

There is no one soft spray program that can be recommended for soft growers in the Wenatchee Valley but, based on WVPP observations, several pesticide options can be suggested. The following list is not all-inclusive, but many WVPP growers have used only these materials, or less, with good results.

Delayed dormant to finger bud: Surround (multiple applications), sulfur, oil, Thiodan
Popcorn: Esteem, oil, mating disruption
Petal fall: Esteem, oil
Summer: oil, Bt, Intrepid, tree washes

Costs
Pesticide costs in most Wenatchee Valley pear orchards in recent years were at least $600 to $800/acre. Pesticide costs in the WVPP soft blocks averaged $435/acre in 1999, $395 in 2000 and $390 in 2001. The three least expensive pest control programs each year, all soft and all with good pest control, averaged $420 in 1999, $295 in 2000 and only $235 in 2001. Costs fell in many soft blocks as biological control provided more help and growers adopted the more cost-effective pest control practices. Costs for the WVPP conventional blocks also dropped ($595-1999, $635-2000, and $470-2001) as these growers implemented more economical practices.

Limitations of Soft Programs
Not all Wenatchee Valley pear growers will adopt soft pest management programs, nor should they. Several key limitations to further adoption persist.

- Pear psylla populations can build to high levels and cause fruit marking in at least the first year that most blocks transition to a soft program. Of the ten soft blocks followed in the WVPP, seven had over 10% of the fruit with psylla marking (a cumulative area of russet the size of a nickel or greater) in Year 1.
- Proximity to native habitat is important as a source of natural enemies. Blocks that are isolated from wild lands may need two or more years until biological control is well established.
- Soft programs are more information and management intensive. They require more regular monitoring of pests and natural enemies, and more assistance in determining how to use the information gathered.
- There is a greater risk of fruit marking in soft programs. This will change when we develop and repeatedly demonstrate soft programs that provide more consistent control.

CONCLUSIONS
Many Wenatchee Valley pear growers can reduce their pest control costs by incorporating soft pest control measures and increasing biological control in their orchards. However, these growers must have the ability to manage a more information intensive pest management program and accept a higher degree of risk.

Taking a longer term perspective, pear growers need to reduce the almost sole reliance upon pesticides that has characterized pear pest management over the past five decades. Pear psylla have become resistant to a long list of insecticides and there is no reason to think the future will be any different. Encouraging and conserving natural enemies can lead to more economical and more stable pear pest management programs, in which resistance develops slowly or not at all and pest control costs are kept relatively low.

The WVPP encouraged the development of soft programs at a time when they were needed as never before. Many of the pest control practices that were investigated and adopted have utility for all Wenatchee Valley pear growers, whether biological control is a factor in their orchards or not. Further research studies and implementation projects are needed to help growers adapt and compete in this time of rapid change.

BUDGET:
Project duration: 1999-2001
FUNDING HISTORY: 1999: $15,000 2000: $14,300 2001: $14,200

Funding	**Year 1 (1999)**	**Year 2 (2000)**	**Year 3 (2001)**
Funds from WTFRC	$15,000	$14,300	$14,200
Funds from other sources	$15,000	$19,354	$6,200
Total	**$30,000**	**$33,654**	**$20,400**
Expenses			
Item	**Year 1 (1999)**	**Year 2 (2000)**	**Year 3 (2001)**
Salaries	$14,500	$16,000	$16,000
Wages	$7,195	$6,751	$5,128
Payroll taxes	$784	$882	$716
Equipment	$1,560	$0	$0
Supplies	$2,695	$1,545	$1,692
Travel	$1,060	$1,709	$1,733
Miscellaneous	$20	$345	$1,077
Total	**$27,814**	**$27,232**	**$26,346**

Table 1. Summary tables of WVPP monitoring data, 1999-2001 (original 15 blocks only)

Psylla adults/tray - High count, March (pre-treatment)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	conv	soft
1999	16.0	24.7	38.0	42.0	44.0	28.0	43.0	15.0	14.0	22.0	15.0	23.0	17.0	12.0	10.0	22.2	26.0
2000	32.9	16.0	5.4	29.8	24.8	12.6	29.1	11.6	10.7	43.6	9.5	9.4	14.8	24.0	17.3	23.8	15.6
2001	6.8	30.6	19.1	22.4	12.2	22.0	32.7	22.2	15.9		13.6	10.5	24.6	13.0	14.6	21.1	17.2

Pear psylla nymphs - per top shoot leaf, July average

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	conv	soft
1999	0.02	1.28	7.50	11.63	1.75	5.08	2.47	0.06	2.73	1.70	4.05	0.88	6.50	2.00	2.93	1.20	5.27
2000	0.38	0.94	3.14	0.36	0.54	0.44	0.88	0.28	0.31	0.70	0.28	0.46	1.28	0.72	0.40	0.62	0.84
2001	0.02	0.46	0.51	0.67	1.15	1.16	0.58	0.33	0.27		0.14	0.03	0.30	0.51	0.25	0.38	0.50

Grape mealybug - % infested shoots, August average

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	conv	soft
1999	0%	22%	0%	62%	43%	6%	49%	2%	0%	2%	0%	0%	0%	0%	0%	11%	14%
2000	0%	0%	0%	15%	30%	0%	73%	0%	0%	0%	0%	0%	0%	0%	11%	10%	7%
2001	4%	13%	0%	8%	64%	10%	53%	5%	0%		0%	13%	3%	3%	0%	15%	11%

Grape mealybug - per tray, August average

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	conv	soft
1999	0.00	0.08	0.00	0.75	0.90	0.18	2.90	0.00	0.05	0.18	0.00	0.02	0.05	0.00	0.15	0.45	0.26
2000	0.00	0.03	0.00	0.11	1.88	0.00	4.44	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.21	0.64	0.28
2001	0.01	0.04	0.00	0.06	0.23	0.03	0.66	0.01	0.00		0.00	0.03	0.04	0.00	0.01	0.14	0.04

Twospotted spider mite - mites/leaf, August average

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	conv	soft
1999	0.24	0.52	0.62	0.85	2.14	1.27	1.67	1.60	1.82	0.01	2.31	2.41	2.61	2.97	3.33	1.35	1.87
2000	0.21	0.60	0.06	1.30	0.40	1.59	0.43	0.71	0.40	6.20	1.18	2.55	1.28	4.93	0.85	2.23	0.88
2001	0.08	0.05	0.02	0.01	0.22	0.03	0.48	0.00	0.01		0.00	0.00	0.01	0.26	0.14	0.17	0.05

Pear rust mite - per spur leaf, August average

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	conv	soft
1999	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	4.50	0.00	0.00	0.00	0.00	0.00	0.59
2000	0.00	0.00	0.00	1.40	0.00	0.90	0.00	0.00	0.50	0.00	22.00	0.00	0.00	0.00	0.30	0.00	3.14
2001	0.00	0.00	0.27	1.87	0.17	5.70	0.00	0.00	1.87		1.77	0.10	0.00	0.00	3.73	0.00	1.72

Codling moth - average per trap, season

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	conv	soft
1999	1.5	0.0	15.3	45.0	0.0	240.7	14.3	0.8	0.0	11.0	0.5	2.8	49.7	17.0	3.5	6.8	44.3
2000	0.5	0.7	3.0	79.0	0.0	76.0	16.0	0.3	1.0	13.0	3.0	1.0	6.0	46.0	5.0	11.1	21.6
2001	3.0	0.5	5.0	192.0	1.0	7.3	17.3	0.0	1.3		2.5	4.8	0.7	15.7	2.5	7.3	24.1

Obliquebanded leafroller - total per trap, 1st generation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	conv	soft
1999	29	31	1	8	85	64	8	36	116	0	109	191	12	29	0	46.3	49.4
2000	15	27	232	14	22	71	5	113	697	0	402	140	189	5	116	43.6	217.9
2001	24	30	1	7	79	64	6	36	114		3	93	190	12	30	21.6	64.6

Pandemis leafroller - total per trap, 1st generation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	conv	soft
1999	56	43	56	534	674	25	120	13	16	3	1	9	10	8	28	36.0	168.0
2000	138	22	51	145	558	19	114	31	9	5	15	6	2	3	130	45.6	116.1
2001	10	3	0	13	147	9	7	8	9		0	1	0	2	9	6.0	20.9

Deraeocoris - per tray, July-August average

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	conv	soft
1999	0.00	0.00	0.64	0.75	0.01	0.53	0.01	0.00	0.18	0.05	0.36	0.00	0.16	0.11	1.16	0.02	0.47
2000	0.00	0.06	1.19	0.57	0.52	1.01	0.02	0.00	0.31	0.00	0.595	0.00	0.50	0.01	0.79	0.01	0.69
2001	0.00	0.00	0.66	0.05	0.10	0.40	0.01	0.00	0.09		0.12	0.03	0.01	0.00	0.07	0.00	0.17

Campylomma - per tray, July-August average

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	conv	soft
1999	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.10	0.00	0.04	0.00	0.60	0.00	0.10	0.00	0.11
2000	0.03	0.08	0.01	0.39	2.35	0.29	0.00	0.00	0.31	0.00	0.46	0.00	0.28	0.03	0.17	0.02	0.53
2001	0.00	0.03	0.01	0.97	0.23	0.51	0.03	0.00	0.12		0.07	0.02	0.02	0.04	0.04	0.02	0.22

Trechnites - per tray, August average

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	conv	soft
1999	0.00	0.00	0.00	0.20	0.00	0.18	0.00	0.00	0.28	0.00	0.05	0.00	0.00	0.00	0.08	0.00	0.10
2000	0.00	0.03	0.33	1.88	0.30	2.00	0.00	0.00	0.43	0.00	0.06	0.00	0.13	0.00	0.23	0.00	0.67
2001	0.03	0.03	0.05	0.13	0.04	1.38	0.00	0.01	0.06		0.04	0.00	0.03	0.01	0.41	0.02	0.24

Earwigs - July-August trap catch (normalized for trap type)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	conv	soft
1999	0.0	3.0	3.0	19.0	20.0	9.0	35.0	0.0	5.0	3.0	100.0	4.0	42.0	26.0	30.0	10.1	28.5

2000	2.4	0.0	21.7	3.6	3.6	3.6	9.6	0.0	63.9	2.0	20.5	6.0	100.0	18.1	21.7	5.4	29.8
2001	4.8	9.5	16.7	11.9	52.4	19.0	3.3	1.9	100.0		42.9	3.3	45.2	6.7	9.5	5.2	33.4

Fruit damage - by major culprit

Psylla	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**conv**	**soft**
1999	0.5%	0.3%	9.4%	-	-	20.1%	-	1.2%	3.4%	15.0%	31.9%	13.8%	47.2%	6.1%	38.0%	6.2%	25.0%
2000	1.6%	1.8%	11.6%	0.7%	8.6%	1.0%	12.9%	0.7%	0.0%	0.1%	0.1%	0.8%	1.8%	0.8%	0.5%	2.7%	3.0%
2001	0.0%	0.5%	4.2%	10.1%	12.4%	15.6%	9.9%	0.3%	0.0%		0.0%	0.1%	0.9%	1.5%	2.5%	2.4%	5.1%

GMB	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**conv**	**soft**
1999	0.0%	12.9%	0.0%	-	-	6.9%	-	0.4%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.2%	2.2%	1.3%
2000	0.0%	0.9%	0.0%	3.2%	14.9%	0.9%	34.4%	0.0%	0.0%	0.1%	0.0%	0.2%	1.0%	0.0%	0.9%	5.1%	2.6%
2001	0.2%	0.2%	0.0%	0.0%	4.5%	0.0%	0.9%	0.0%	0.0%		0.0%	0.7%	0.0%	0.0%	0.4%	0.3%	0.6%

Leafroller	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**conv**	**soft**
1999	0.0%	0.0%	0.1%	-	-	0.0%	-	0.4%	2.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.4%
2000	0.0%	0.4%	2.9%	0.6%	0.0%	0.0%	0.2%	0.3%	0.9%	0.0%	2.1%	0.1%	3.6%	0.5%	0.2%	0.2%	1.3%
2001	0.0%	0.0%	0.1%	0.0%	0.7%	0.0%	0.0%	0.0%	0.2%		0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%

Box elder/

Stink bug	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**conv**	**soft**
1999	0.0%	0.0%	0.0%	-	-	0.0%	-	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
2000	0.3%	0.4%	0.6%	0.9%	0.4%	1.8%	0.1%	0.6%	0.9%	0.8%	0.3%	1.1%	1.6%	0.0%	4.0%	0.5%	1.3%
2001	0.0%	0.4%	3.0%	1.7%	0.2%	0.9%	0.2%	1.2%	0.5%		1.8%	1.8%	1.1%	0.5%	2.1%	0.5%	1.5%

Rust mite	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**conv**	**soft**
1999	0.0%	0.0%	0.0%	-	-	0.0%	-	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2000	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2001	0.0%	0.0%	0.5%	4.9%	0.0%	23.1%	0.0%	0.0%	9.1%		92.7%	0.0%	0.0%	0.0%	1.0%	0.0%	14.6%

Pesticide costs - per acre

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**conv**	**soft**
1999	$744	$473	$416	$369	$625	$592	$572	$508	$236	$742	$300	$665	$425	$459	$528	$595	$436
2000	$657	$544	$306	$592	$432	$569	$473	$631	$340	$800	$329	$762	$305	$572	$279	$634	$394
2001	$463	$411	$338	$418	$493	$400	$461	$461	$404		$570	$505	$186	$561	$187	$471	$389

FINAL REPORT

Project Title: Pear IPM: Area-wide movement patterns of psylla and its interaction with chemical use and natural enemy abundance**.**

Project leader: Tom Unruh
Organization: USDA-ARS, Wapato WA

Cooperators: David Horton

Funding History:
Year initiated: 2000 $25,000
Final Year: 2001 $15,000

Objectives:
1) Measure pear psylla nymph and adult abundance, beneficial insect abundance, chemical use patterns and tree vigor in ca. 30 PIPM and 10 conventional blocks (2001)
2) Collect psylla adult abundance in spring and fall to describe more completely movement among orchards (2000)
3) Use multivariate and spatial statistical methods to identify the factors most predictive of good psylla control and provide a prescription for best IPM practices based on 1999-2000 Pew-EPA data and our own data collected in 2001. (2000-2001)
4) Evaluate accuracy of presence-absence sampling methods for psylla nymphal abundance. (2000-2001)

Significant Findings

- Differences in psylla abundance among orchards are very high in fall and fairly homogeneous in spring, indicating movement through winter produces regional population pressures. This supports an area-wide management approach as currently being proposed by John Dunley for Wenatchee pear orchards. Data not shown.
- In 1999-2001, psylla abundance was similar or lower in "soft" IPM blocks compared to "hard" or more conventionally managed blocks.
- Cost savings were observed in the Yakima Pew-EPA pear IPM project for growers using mating disruption and reduced Organophosphates but these savings did not continue in 2001.
- Predators were more abundant in soft blocks on a per/psylla basis.

Methods:
Psylla abundance was measured using standard beat tray and leaf sampling methods. Twenty to 25 beat trays were taken per block on any given sampling date. 100 leaves (50 inner and 50 outer) were used for leaf samples and 15 shoots for shoot samples. In studies of presence/absence sampling, the proportion of shoots infested, and the proportion of the 1st fully expanded leaf, middle, and basal leaves infested were also enumerated. We used beat trays to measure relative predator abundance. Pesticide data was provided by DelMonte for their growers in 1998-2000 in association with the Pew-EPA project, and were sent to us directly by cooperating growers in 2001. Leaf brushing was conducted 5 times during the year, in May June, July, and August. Beat tray data was taken 7 times during the

Statistical analyses were correlative, using partial regression to measure the influence of certain pesticide use practices on predator abundance and seasonal psylla densities. Comparisons between management programs in 1999-2000 was based on membership in the Pew-EPA study versus all other pear growers in the Yakima Valley and versus 5 control orchard blocks that used a conventional

management approach (did not use mating disruption). In 2001, 25 former Pew-EPA blocks and 10 nominally conventional blocks were employed.

Results and Discussion:

Pesticide usage in the Yakima Valley in 1999-2000 was 20% less overall in Pew-EPA implementation blocks—enough so to reduce pesticide + pheromone costs to $30 to $50 below average (See report to Washington Horticultural Association, Jeff Conner,

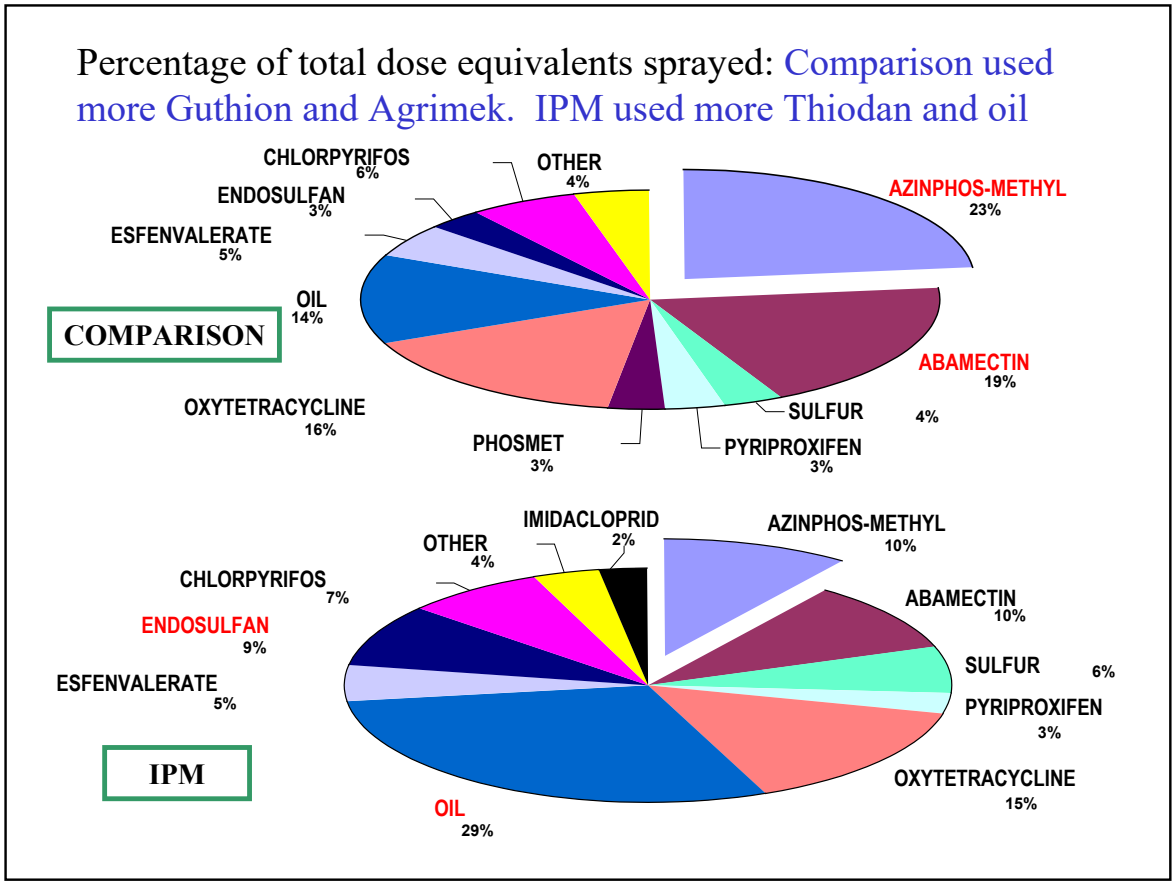
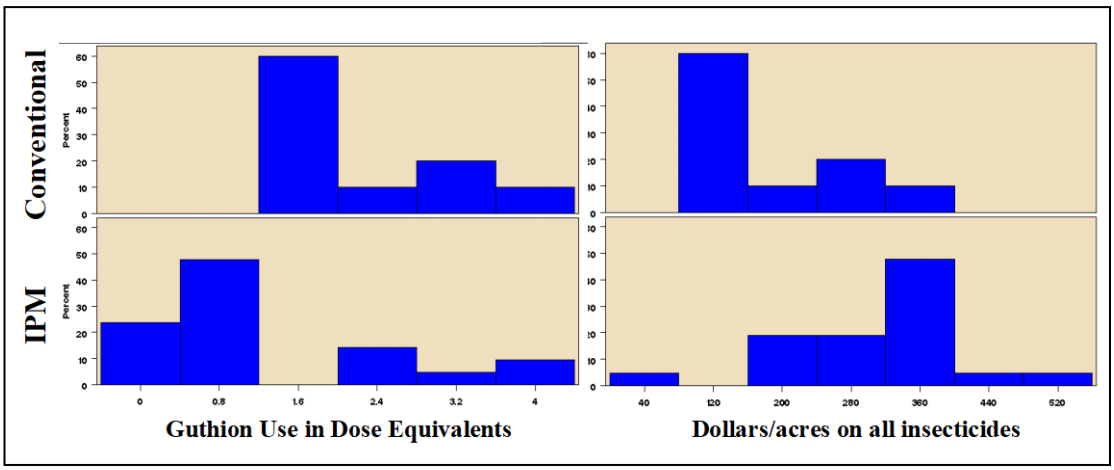


Figure 1. Pesticide use in 1999-2000:Pew-EPA versus conventional cannery pear blocks in the Yakima Valley.

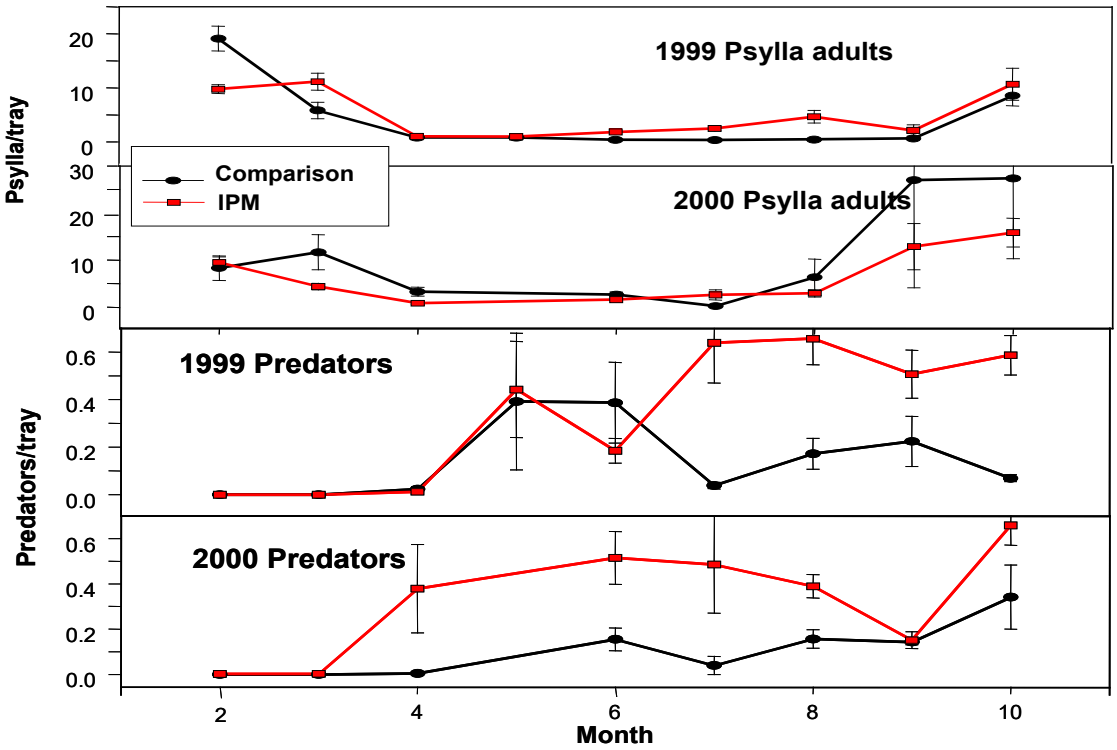
Oregon State University). Figure 1 shows azinphosmethyl and abamectin were used less by Pew-EPA growers compared to all other blocks (Yakima Valley-wide insecticide use in cannery pears). Also, IPM growers tended to more often use reduced rates of insecticides. About 1/3 of materials were applied at full rates by IPM growers while over ½ of materials were used at full rate in the Yakima Valley in general (not shown). In 2001, there was a significant retrenchment of pesticide use practices. Specifically, there almost $100 more spent by IPM growers (as defined by former membership in Pew-EPA project and use of MD for codling moth control) than conventional growers (Fig 2) . There was also a great range in Guthion use by IPM growers as seen in Figure 2.

Figure 2. Pesticide Use in 2001 in 25 IPM and 10 Conventional cannery pear blocks.



Psylla abundance was similar between Pew-EPA and conventional orchards during the growing season (Fig 3) but variation in psylla among blocks within programs was high. In 2001 we re-classified orchards based on pesticide use patterns. We grouped orchards that used 1 or more organophosphate applications after May into "hard. Thus under "soft" we had 4 growers that used 1 azinphos spray in May and several others that used no azinophos. Variation in psylla levels was high among orchards of each management type in both leaf brush and beat tray data in 2001 (Fig 4) but there was a trend for lower psylla levels in soft blocks. Predators were usually more abundant in IPM or soft blocks in 1999-2000 but not in 2001 (Fig 4). However, predator to prey ratios were significantly higher in soft blocks (Fig 4). Three key predators were seen: *Campylomma, Deraeocoris*, and lacewings. *Campylomma* was up to 5 times more abundant than all other predators in 1999 through 2002 (not shown).

Figure 3. Psylla and predator levels in 1999-2000.



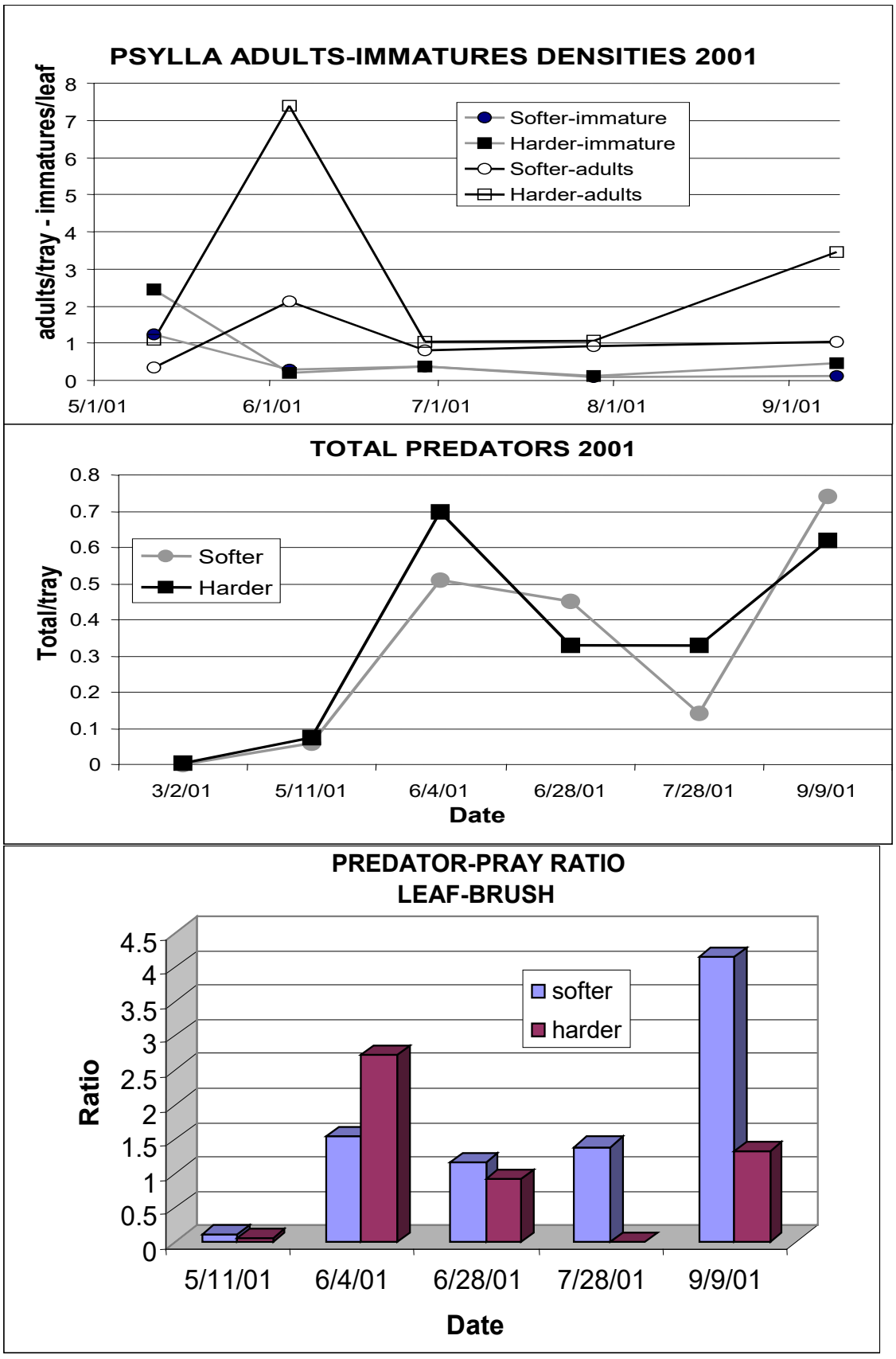
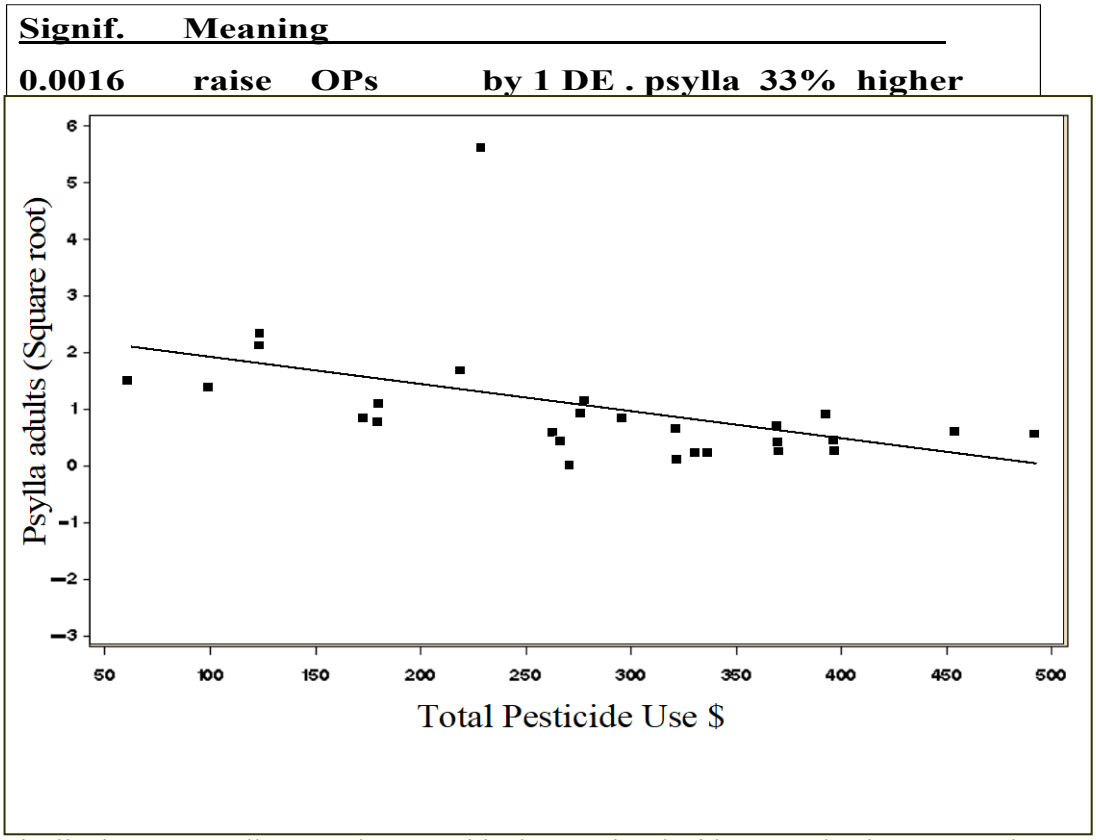


Figure 4. Psylla abundance and predator levels in 2001.

Psylla and predator abundance were influenced by pesticide use patterns (Figs. 3 and 4). To tease out other effects of pesticides I conducted a partial regression analysis. The results show (Fig 5) that use of Agrimek in early and mid-summer reduced psylla as expected. Interestingly, broad-spectrum chemicals used in the delayed dormant period were also negatively correlated to psylla abundance measured in July and August. Also, as obvious from above, guthion use enhanced psylla. Results of the regression study are shown as the effect in percentage increase of psylla after a one dose equivalent increase in use of the 3 classes of materials. Broad-spectrum insecticides used in pre-bloom were predominantly Thiodan and Asana. The benefit of this spring control was a constant message from Dr. Everett Burts and it apparently remains true. Unfortunately, in the Yakima Valley, spring use of Surround was trivial during this study period, so the potential of substituting it for more strident chemicals cannot be tested.

Figure 5. Interpretation of partial regression analysis of pesticide use on psylla abundance.



Finally, in 2002, psylla control was positively associated with cost. That is, growers that spent more on insecticides got better psylla control (Fig 6.) and appears to stem from widespread use of Agrimek and Provado in late May and July.

Figure 6. Psylla density in May through August compared to $$ spent on control.

Presence-Absence Sampling. These investigations are incomplete because of several difficult problems encountered. First, we find that visual observation tend to underestimate actual infestation percentages. This is outlined in Figure 7 . In general, using a head visor, the percentage of leaves infested is underestimated by 30%.

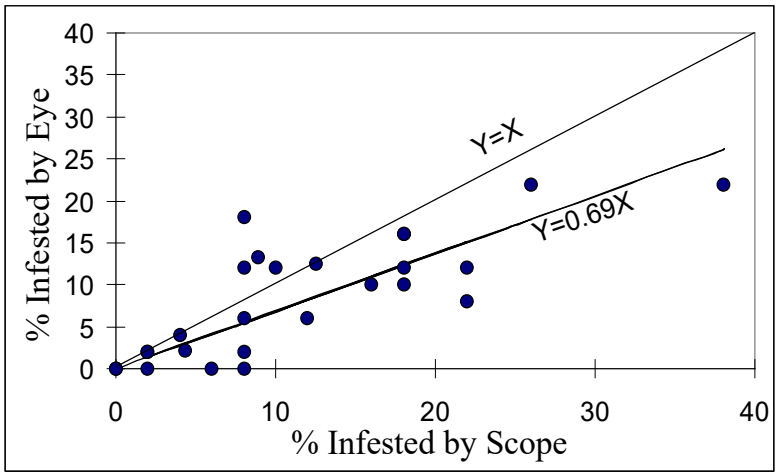


Figure 7. Percentage infested leaves by method

A second, more important observation, is the inadequacy of sample sizes that would be considered manageable by a pesticide consultant. In Figure 8 I show the percentage infested shoots and versus the average number of psylla/leaf when taking 15 top shoots and 3 leaves per shoot. The troubling observation is that there are outliers or extreme values where the percentage infested is low and the number of psylla per leaf is high. These are highlighted.

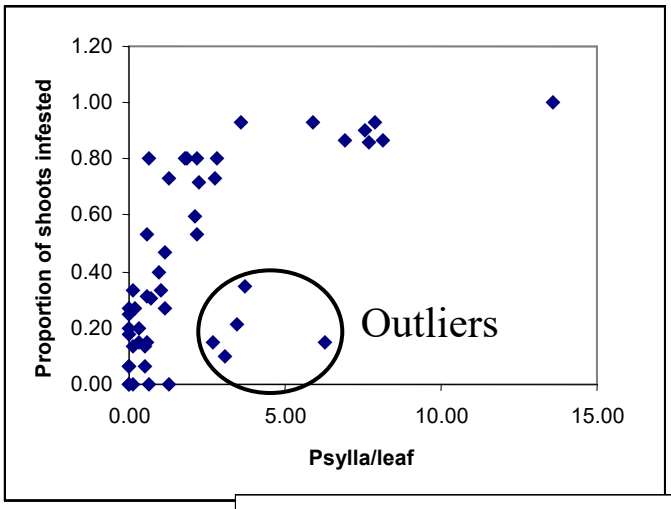


Figure 8. Outliers are a problem with small samples

Finally, there we have collected samples that show that an increase in the sample unit size can reduce this outlier problem. In Figure 9. you can see how increasing the saqmple unit to 5 leaves from 1, tightens up the relationship between proportion infested and psylla density. In the coming months we will try to more accurately estimate an optimal sample unit on which to count proportion infested (number of leaves). Until I find a sampling approach with the desired accuracy and ease of I will not make recommendations or publish a design for the use of Washington for pest consultants.

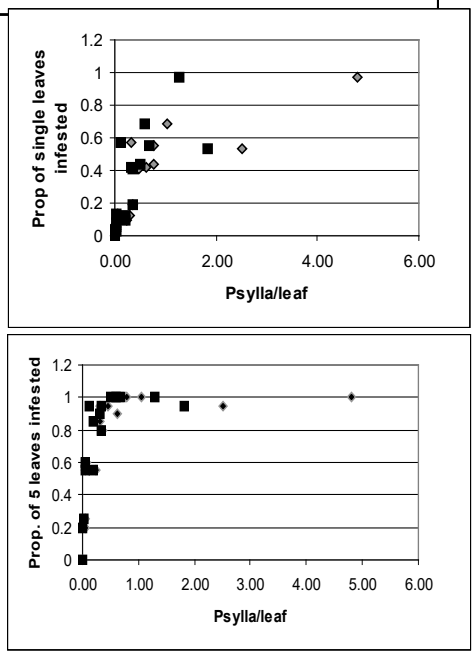


Figure 9. Proportion of 5 leaf and 1 leaf sample units infested versus psylla density. 5-leaf sample units are more accurate.

FINAL REPORT
WTFRC Project No.: PR-01-97 **Organization Project No**: ARS 14104

Project Title: Maturity and Storage of Winter Pears

PI: Stephen R Drake, Research Horticulturist

Organization: USDA, ARS, TFRL, 1104 N. Western Avenue Wenatchee, WA 98801

Objectives:
1. Determine type and time of atmosphere establishment in conjunction with different maturity levels to optimize storage of winter pears.

2. Complete studies presently in progress concerning maturity and storage of 'Bosc' pears and disorder associated with the long-term storage of 'Anjou' pears.

Significant Findings:
1. 'd'Anjou' pears were packed in six commercial paper wraps (dry; 3% oil; 3% oil with copper and ethoxyquin; 6% oil; 6% oil with ethoxyquin; 9% oil). After packing pears were placed in three different (1.5% oxygen & 1% carbon dioxide; 1.5% oxygen & 3% carbon dioxide; 1.5% oxygen & 1% carbon dioxide for 60 days, followed by 4% oxygen for 60 days and then 6% oxygen for 60 days) controlled atmosphere storage conditions. Pears were stored for 120 and 210 days with an additional 30 days in regular atmosphere storage to simulate shipping and handling. Objective quality evaluations were conducted after each storage period and sensory evaluations after 210 days of storage. Paper type influenced both the peel and flesh color of pears before and after ripening, but did not influence firmness, soluble solids or acid content. Sensory ratings of appearance and incidence of disorders were unacceptable for pears stored in the variable atmosphere wrapped in dry or paper containing only 3% oil. **The disorder "Black speck" was present in pears wrapped in paper with 6% oil and stored in an atmosphere of 1.5% oxygen and 1% carbon dioxide.** Pears stored in an atmosphere of 1.5% oxygen and 3% carbon dioxide received acceptable sensory scores regardless of paper type.

2. ‘d’Anjou’ and ‘Bartlett’ pears (*Pyrus communis* L.) were treated with 12% CO_2 for 14 days at -1C and then stored in either regular (RA) or controlled-atmosphere (CA) storage for various periods of time. After each storage period, pears were evaluated for quality attributes. Compared to non-treated fruit, CO_2-treated ‘d’Anjou’ pears from RA storage were firmer, greener, and displayed reduced rot, scald and internal breakdown and better pedicel condition. High CO_2 treatment of ‘Bartlett’ pears prior to RA storage resulted in reduced quality after storage. Pre-storage CO_2 treatment of ‘Bartlett’ pears reduced post-storage firmness and TA and increased incidence of scald, but reduced surface damage during ripening. High CO_2 treatment prior to 120 or 220 days of CA storage had no effect on the post-storage quality of either ‘d’Anjou’ or ‘Bartlett’ fruit.

3. Loss of 'Anjou' pear quality after 90 days of storage (60 days at 1.5% O_2 & <1.0% CO_2; then 30 days at 4% O_2) was apparent in this study. Distinct color changes from green to yellow in the peel and a more yellow flesh, coupled with a loss of firmness, for 'Anjou' pears even after only a short period (30 days) in elevated O_2 was evident. Use of elevated CO_2 (3%), in CA storage, resulted in a greener peel and firmer pears with less change in flesh color, and superior stem condition after 150, or 210 days of storage compared to pears from 1.5% O_2 and <1% CO_2. After controlled atmosphere and an additional 30 days of storage in regular atmosphere, quality differences in 'Anjou' pears from the different atmospheres (1.5% O_2 & <1.0% CO_2; variable O_2; 1.5% O_2 & 3.0% CO_2) were even more manifested. Pears in elevated O_2, displayed reduced firmness, finish and stem condition and

enhanced shrivel. Pears in 3.0% CO_2, compared favorably in all quality considerations with pears from a normal (1.5% O_2 and < 1.0% CO_2) atmosphere. No pithy brown core was evident in 'Anjou' pears regardless of storage atmosphere.

4. 'Anjou' pears were subjected to seven different controlled atmosphere storage practices (1. CA of 2% oxygen and 1% carbon dioxide; 2) Ca for 90 days and then regular air atmosphere for the remainder of the study; 3) cool pears to a uniform -1C and then establish normal CA in <12 hours; 4) warm pears to a uniform 15C and then establish CA in <12 hours; 5) slow oxygen removal from 21 to 2% over a period of 10 days; 6) CA for 90 days, RA for 15 days then back to normal CA; 7) 90 days normal CA then 4% oxygen for 60 days then 8% oxygen for the remainder of the study) and stored at 1C, for 90, 150 and 210 days plus 30 days at regular atmosphere. CA storage treatment conserved pear qualities to a certain extent regardless of storage treatment. **Establishment of CA conditions on warm pears prior to cooling, resulted in reduced firmness, finish and color and increased amount of scald, shrivel and physiological disorders**. Pears held in CA with variable oxygen (2% for 90 days, 4% for 60 days, 8% remainder of storage) resulted in very poor quality pears.

5. 'Anjou' and 'Bosc' pears were harvested one to two days prior to commercial harvest from three orchards in the Wenatchee, Washington growing district. Harvest fruit were treated with 300 ppm ethylene for three days and 20C. Ethylene treatment enhanced yellow color on fruit peel and the reduction of flesh firmness and increased spoilage after 90 days in either regular atmosphere storage or controlled atmosphere storage regardless of cultivar. Ethylene-treated fruit, of both cultivars, stored in CA had a longer storage life than fruit stored in RA. **The safe storage period of ethylene-treated 'Anjou' and 'Bosc' pears was 90 and 45 days, respectively, in RA and 120 and 90 days, respectively, in CA**.

6. 'Bosc' pears were placed in a purge-type controlled atmosphere storage immediately after harvest (<24 hours) and held for 180 days at 1C. Oxygen in all atmosphere as 1.5% and carbon dioxide was 1, 3, or 5%. Pears were evaluated immediately after removal from CA storage and after ripening for an additional 7 days at 21C. **Pears stored in 3% carbon dioxide were firmer, had superior finish, with significantly reduced decay and internal breakdown than pears stored in 1% carbon dioxide.** In 3% carbon dioxide, pears retained the ability to ripen **after** long-term storage. A 10-day delay in atmosphere establishment had little or no influence on the long-term keeping quality or ripening ability of 'Bosc' pears. Firmness, soluble solids content and starch, either alone or together, were good indices of maturity for 'Bosc' pears.

. 'Gala' apples and 'Bartlett pears were harvested over two crop seasons at different maturities and growing sources then stored in refrigerated storage alone and in controlled atmosphere storage (1% oxygen and 1% carbon dioxide, or 2% oxygen and 3% carbon dioxide). Before and after storage of 45 or 90 days, the juice from the fruit was examined for carbohydrate and acid composition and contents. For 'Gala' apples, the type and length of storage had no significant effect on juice carbohydrate and acid contents compositions, however the time of harvest greatly influenced both parameters. Storage atmosphere did not affect the carbohydrate and acid contents and compositions of 'Bartlett' pear juice, however the source of the fruit and subsequent amount of ripening did appear to significantly cause changes in the same parameters. The carbohydrate and acid compositions and contents of 'Gala' apple juice were within the compositional range for worldwide apple juice. 'Bartlett' pear juice contained significantly greater concentrations of citric acid than shown in previously published studies.

Budget:
Maturity and Storage of Winter Pears
Stephen R Drake
Project Duration: 1999-2001

Year	Year 1 (1999)	Year 2 (2000)	Year 3 (2001)
Total	$18,750	$35,700	$37, 800
Current Year Breakdown			
Salaries[1]	12000	24000	29090
Goods and Services	3000	4000	6000
Benefits	3500	7500	2410
Travel	250	200	300

[1]Salary for temporary technical support.

Project total: $92,250

Publications:

Drake, S.R. and T.A. Eisele. 1999. Carbohydrate and acid contents of Gala apples and Bartlett pears from regular and controlled atmosphere storage. J. Agric. and Food Chem. 47:3181-3184.

Drake, S.R. and R.D. Gix. 1999. Response of 'Anjou' winter pears to commercial controlled atmosphere storage conditions. Proc. Wash. Tree Fruit Postharvest Conf. 15:77-81.

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Drake, S.R. 1999. Elevated carbon dioxide storage of 'Bosc' pears. J. Food Qual. 22:417-425.

Shu-shang, MA, P.M. Chen, D.M. Varga and S.R. Drake. 2000. Ethylene capsule promotes early ripening of 'd'Anjou' pears packed in modified atmosphere bags. J. Food Qual. 23:245-259.

Drake, S.R. and P.M. Chen. 2000. Storage quality of ethylene treated 'Anjou' and 'Bosc' winter pears. J. Food Proc. and Pres. 24:379-388.

Drake, S.R., R.D. Gix and C. Coureau. 2001. Quality of 'Anjou' pears after different types of controlled atmosphere storage. J. Food Qual. 24:27-36.

Drake, S.R., D.C. Elfving and R.D. Gix. 2001. The influence of paper wraps on the quality of 'd'Anjou pears after controlled atmosphere storage. HortScience 11:566-570.

Drake, S.R. The influence of paper wraps on the quality and disorders of 'd'Anjou' pears after controlled atmosphere storage. Proc. Washington Tree Fruit Postharvest Conf., March 2001.

Drake, S.R. and D.C. Elfving. Influence of prestorage carbon dioxide treatments on the quality of 'd' Anjou and 'Bartlett' pears. J. Food Proc. and Pres. (Accepted).

Drake, S.R. and R.D. Gix. Quality of 'Anjou' pears from variable oxygen and high carbon dioxide controlled atmosphere storage. J. Food Qual. (Accepted).

Appreciation is expressed to: Blue Star, Blue Bird, Dovex, Independent, Peshastin HiUp, Stemilt and Wrap Pack, for their cooperation in the above studies.

FINAL REPORT

Project title:	Reducing Storage Disorders with Natural Plant Oils
PI:	Eric Curry, Plant Physiologist
Organization:	USDA, ARS, TFRL, Wenatchee, WA
Co-PI(s) and affiliation(s):	Zhiguo Ju, Research Associate, USDA, ARS, TFRL, Wenatchee, WA
Cooperator(s):	Peter Sanderson, Plant Pathologist, WTFRC; Eugene Mielke, Horticulturist, OSU (ret)

Objectives: As an alternative or adjunct to present chemical treatments, to study the efficacy of vegetable oil emulsions on 'd'Anjou' and 'Bartlett' pears in storage trials of commercial scale.

Storage disorders and fruit decay are two major issues that affect profitability of the fruit industry. Scald (including superficial scald and senescent scald) and internal browning (including senescent breakdown, core browning, and flesh browning) are the major physiological disorders that develop after prolonged regular storage. Although postharvest fruit decay often occurs after months in storage, the innoculum is often present when fruit are placed in storage. Gray mold (*Botrytis cinerea*) and blue mold *(Penicillium expansum*) are the main decay causing pathogens in the Pacific Northwest.

Currently, no effective measures are available to control senescent scald or internal browning except fruit maturity and temperature management. Ethoxyquin or oiled papers without ethoxyquin are used to assist in the prevention of superficial scald, whereas fungicides are the primary tools in controlling fruit decay during storage. With chemical or fungicide dependency, however, there is no immunity from the constant challenges of 1) induced or natural pathogen resistance; 2) tightened regulations from foreign markets; or 3) increasing regulatory pressure stemming from consumer advocacy groups regarding chemical use in food or food products. Development of chemical alternatives that are effective and environmentally friendly would be highly beneficial to the fruit industry.

Early in 1919, Brooks *et al*. reported that fruit wrapped with tissue paper containing 15% mineral oil developed less scald after cold storage. Although this method is quite effective, and still in use in Washington, Oregon, and California, it was abandoned by many countries after the commercialization of DPA and ethoxyquin. Since the early 90s, the effects of surface oil treatments on fruit quality and storage disorders have been studied. Scott *et al*. (1995) in Australia showed that wiping fruit with both vegetable oil (canola, caster, palm, peanut, and sunflower) and petroleum oil effectively reduced scald development in 'Granny Smith'. Curry (2000) found that scald was reduced in 'd'Anjou' pears, 'Red Delicious' and 'Granny Smith' apples when fruit were wiped with wheat germ oil. The practical application of wiping fruit with plant oils, however, is limited because: 1) it is hard to get uniform coverage; 2) additional machinery may be required in the packing houses thereby adding cost; 3) its inhibition on scald is time dependent and does not meet requirements for practical usage; and 4) the application method may increase greasiness on the fruit surface which is undesirable.

Instead of wiping fruit with oil, Ju *et al*. in 1990 (personal communications) and Curry in 1992 used oil emulsions to treat fruit and effectively controlled scald in apples. Oils from corn, soybean, peanut, cottonseed, and linseed are equally effective, and the formulation developed by Ju *et al*., is stable, and leaves no greasiness on fruit surface either at application or after storage. The fungicidal property of edible plant oils, on the other hand, has not been well studied and the few reports available are contradictory. In one report, both canola and soybean oil at 1% were effective in controlling apple

powdery mildew (*Podosphaera leucotrica*), but had no effect on brown rot of peaches (Northover and Schneider, 1991, 1993) or black knot (*Piosporina morbosa*) on leaves of plum and cherry. Duan *et al*., (personal communication) on the other hand showed that edible plant oils at 5 to 10% were effective in reducing decay severity (not % incidence) caused by gray mold (*B. cinerea*), blue mold (*P. expansum*) and bitter rot (*Glomerella cingulata*) in apples and pears.
Data from initial trials in our laboratory (Ju and Curry, 2000) suggest that treatment of 'd'Anjou' and 'Bartlett' pears with natural oil emulsion formulations: 1) inhibited ethylene production and respiration, and delayed fruit ripening and senescence; 2) prevented superficial scald in 'd'Anjou' and senescent scald in 'Bartlett'; 3) controlled core breakdown in 'Bartlett'; and 4) reduced decay severity (not % incidence) of gray mold and blue mold. Fruit treated with oil emulsions were firmer, greener, had higher levels of titratable acidity and showed no scald or internal browning after 3 months for 'Bartlett' or 8 months for 'd'Anjou'. Initial observations also suggest oil treatment reduces fruit shrivel during prolonged storage.

REFERENCES

Brooks, C., Coolly, J.S. and Fisher, D.F., 1919. Nature and control of apple scald. J. Agric. Res. 18, 211-240.

Curry, E. A. 2000. Farnesene and squalene reduce scald in apples and pears. Acta Hort. 518:137-144. (In press).

Ju, Z. and Curry, E. 2000. Stripped corn oil emulsion alters ripening, reduces superficial scald, and reduces coreflush in 'Granny Smith' apples and decay in 'd'Anjou' pears. Postharvest Biol. and Tech. 20:185-193.

Ju, Z. and Curry, E. 2001. Plant oil emulsion prevents senescent scald and core breakdown and reduces fungal decay in 'Bartlett' pears. J. Amer. Soc. Hort Sci. (In press).

Northover, J. and Schneider, K.E. 1991. Efficacy of canola and soybean oils against peach brown rot, 1990. Fungic. Nematicide Tests. 46:69.

Northover, J. and Schneider, K.E. 1993. Activity of plant oils on diseases caused by *Podosphaera leucotricha , Venneria inaequatis*, and *Albugo occidenratis*. Plant Dis. 77:152-157.

Scott, K.J., Yen, C.M.C. and Kim, G.H., 1995. Reduction of superficial scald of apples with vegetable oils. Postharvest Biol. and Tech. 6:219-223.

Significant findings: The final experiment to be evaluated was conducted at Stemilt Growers in September 2000 using the small scale whole-bin drenching facility. The treatments included 1) untreated control, 2) 2.5 % oil, 3) 5% oil, 4) 5% oil + SOPP, and 5) Ethoxyquin (2700 ppm) + SOPP. Although both oil treatments reduced scald similar to that of ethoxyquin, the addition of SOPP to the oil did not reduce the incidence of decay over that of ethoxyquin alone. Severity of decay was reduced with oil treatment commensurate with delay in ripening. The main problem with bin drenching with this facility was that of coverage. Fruit within the top 1/3 of the bin was covered adequately and scald was well controlled. Below this, scald began to increase. Fruit in the bottom 1/3 of the bin had about 25% more scald that that in the top 1/3, but still about 50% less than the untreated control. In the future, proposed commercial treatments using bin drenching should be made with sufficient flow and for sufficient time to provide adequate coverage.

Results and discussion: Experiments were conducted in 2000 to test the applicability of vegetable oil emulsions in commercial warehouses at the following locations: Washington Fruit in Yakima, OSU Hood River Research and Extension Station and Stemilt Corporation in Wenatchee.

At Washington Fruit, 'Bartlett' used for canning was treated with 2.5% oil, and 5% oil on August 23 and stored in regular storage at 29.5 F and in CA (1.5% O_2 and 1% CO_2) at 29.5 F.

Each treatment contained 4 bin replications. Fruit in regular storage were moved to a ripening area November 10 and evaluated November 17. Control fruit were fully ripe and very susceptible to bruising, whereas 2.5% oil treated fruit were ripe but were light green or yellow and firmer with higher acidity. Fruit treated with 5% oil were unripe, green, relatively firmer and had the highest acidity of all the treatments. Oil treatment did not control decay but reduced spread of decay compared with control. Washing the oil-treated fruit with tap water removed traces of emulsion residue, but did not have a significant effect on fruit ripening.

In the bin, fruit contact points showed greasy spots at removal from storage due to more oil accumulation. The accumulation of oil in those areas, however, did not cause any phytotoxiccity or localized changes in ripening behavior either at removal or after ripening which was our major concern about oil-treated fruit stored loosely in the bin. Washing with tap water was effective in removing excess emulsion and no apparent spotting was observed on the fruit surface.

Fruit in CA were removed on November 7. Three boxes of fruit from each bin were taken to Wenatchee and stored at 32 F. Fruit quality was evaluated upon removal from CA on November 10. Control fruit started to lose color, firmness and acidity after 2.5 months in CA. No difference was found between 2.5% and 5% oil treatment and both maintained similar firmness and color at harvest. Acidity decreased slightly but was significantly higher than the control fruit. Another set of fruit were moved to a ripening room on November 7 and evaluated a week later. Fruit treated with 2.5% oil ripened normally with a slight delay in green color loss but with higher firmness and acidity. Fruit treated with 5% oil failed to ripen after 7 days at 20 F. These fruit were green, firm, and had higher acidity than both other treatments. Decay was also reduced. Fruit in Wenatchee will be kept at 34 F for another 2 months.

These results indicate 'Bartlett' pear can be drenched with vegetable oil emulsion without causing deleterious effects. When treated with 2.5% emulsion, fruit ripen normally and maintain better quality after 2 or 3 month in regular storage or after 3 or 4 months in CA storage. When treated with 5% emulsion, fruit should be stored longer to ripen normally - results of fruit quality after 6 months storage (CA + RA) will be presented in February. This offers additional possibilities for the warehouses. Fruit could be drenched at harvest and stored loosely in bins to extend time available for packing high quality fruit. In addition, although oil treatment does not inhibit decay, it reduces development and spread by delaying fruit ripening. Our preliminary trials in the laboratory indicate that when the emulsion is combined with TBZ most of the decay should be controlled. Treated fruit designated for the fresh market have the additional benefit of less scuffling on the packing line due to the delayed ripening and reduced water loss which causes shrinkage and stretching of the epidermis over the stone cell clusters. Also, by packing later, decay infected fruit can be removed thus saving the cost of repacking should decay blossom in boxes instead of bins.

In Hood River, both 'Bartlett' and 'd'Anjou' were drenched with 2.5% and 5% oil emulsion, or line sprayed with 5% or 10% oil emulsion on September 13. Drenched fruit were stored in bins and line sprayed fruit were stored in cardboard boxes in the storage facility at MCREC. Treatments were further subdivided to include either wrapped with plain paper or unwrapped. Untreated fruit served as control. Each treatment contained 3 bins of fruit, and fruit were stored in regular storage.

Fruit samples were taken to Wenatchee on December 4 and stored at 32 F. Fruit quality evaluation will begin in January, 2001. According to preliminary observations, similar results to those observed at Washington Fruit are anticipated. Interestingly, fruit treated by line spray looked and felt greasy at the time of treatment due to evaporation of water in the formulation during the drying process, leaving emulsion residue on the fruit surface. During storage, however, the oil was absorbed by the fruit cuticle and greasiness was barely noticed after 3 months in storage. The fruit wrapped with paper looked even better because the paper absorbed the excess emulsion on the fruit surface.

Budget:
Project duration: 2000 - 2001
Reducing Storage Disorders with Natural Plant Oils
Eric Curry
Original budget request:

Year	2000	2001
Total	34,500	39,500

Publications:

Curry, E.A. and Ju, Z. Improving storage quality of organically grown apples and pears by treating with natural oils. Goodfruit Grower 15:29-30. 2000.

Curry, E.A. Farnesene and squalene reduce scald in apples and pears. Acta Hort. 518:137-144, 2000.

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Duan, Y., Ju, Z., Ju Z. and **Curry E.A.** 2000. Stripped plant oils maintain fruit quality of 'Golden Delicious' apples and 'Bartlett' pears after prolonged cold storage. Posthar. Biol. Tech. 20:185-193. 2000.

Ju, Z. and **Curry E.A.** Stripped corn oil alters ripening, and reduces scald and internal browning in 'Granny Smith' apples and scald and decay in 'd'Anjou' pears. PostHarvest Biology and Technology, 20: 185-193, 2000.

Ju, Z. and **E. Curry**. Plant oil emulsion prevents senescent scald and core breakdown and reduces fungal decay in 'Bartlett' pears. J. Amer. Soc. Hort. Sci. 2001 (In press)

Ju, Z. and **E. Curry**. Vegetable oil emulsion for blossom thinning and pest control in organic fruit production. Proc. Organic Fruit Symposium, 2001, (in press).

CONTINUING REPORT

Title: Epidemiology of Bull's-Eye Rot in Pear

Project Leader: David Sugar, Professor
Oregon State University, So. Oregon Research and Extension Center

Robert A. Spotts, Professor
Oregon State University, Mid-Columbia Research and Extension Center

James E. Rahe, Simon Fraser University, B.C.

Cooperator: Andre Levesque, Agri-Food Canada

Funding History: Year Initiated: 2001
Funding in 2001-2002: 34,149
Funding requested for 2002-2003: 34,149

Objective: To understand the disease cycle of bull's-eye rot in pear, so that vulnerable points can be identified and corresponding control measures implemented effectively.

Significant Findings:
1. The identity of fungi causing bull's-eye rot of pears in Oregon has been determined by PCR analysis to be *Neofabraea alba* and *N. perrenans*, with infrequent appearance of *N. malicorticis*. This is contrary to expectations based on older studies, and may have important implications for the behavior of the disease on pear.

2. Strobilurin fungicides applied two weeks before harvest contributed significantly to bull's-eye rot control under conditions of natural inoculation, and were equivalent to ziram treatments. This may strengthen the control program by emphasizing use of ziram earlier in the season, to be followed by strobilurin sprays closer to harvest.

3. It appears possible to estimate the amount of bull's-eye rot infection that will occur in lots of Bosc pears in long term storage by holding samples at 50° for six weeks.

4. The effectiveness of fungicide treatments against bull's-eye rot, applied in the orchard or as a postharvest drench, depended on the timing of artificial inoculations. As further information on the timing of natural inoculation is developed, the timing of fungicide treatments can improved.

The following studies are in progress; some preliminary results are described below (Results and Discussion), but otherwise experiments are to be evaluated throughout 2002:

5. Determining the time of infection of pear, quince, and apple trees by *Neofabraea malicorticis*, using 1st year apple cankers as source of inoculum. The concept of the experiment is to take successive groups of potted trees from the plastic house and expose them to sources of inoculum for 2-week periods, then remove the inoculum and return the trees to the plastic house.

6. Efficacy of copper fungicide against infection of apple and quince by *N. malicorticis*, in relation to time and frequency of application. *N. malicorticis* is believed to infect through unwounded bark, but how it does so is not known. Infection may occur immediately after spore deposition, or possibly at some subsequent time following a quiescent or epiphytic growth phase on the bark surface.

Differences in the frequency of canker development associated with the two different times of application of inoculum sources, before and after the first fungicide application, may allow distinction between these two possibilities.

7. Determining the ability of the various *Neofabraea* species to cause cankers in pear trees by monthly inoculations with mycelium and with spores. Determining the ability of inoculum to infect through unwounded, wounded, and pruning cut tissues.

8. Determining the timing of pear fruit infection by bagging thousands of fruit and exposing replicate groups for successive two-week intervals.

9. Determining the temperature / wetness relations necessary for fruit infection, as is known for pear scab.

Results and Discussion:
1. Isolates from bull's-eye rot lesions on fruit were sent to Canada for identification. By combining PCR analysis of the fungus DNA and pathogenicity test data, 17 isolates sent from Hood River were identified as 8 *Neofabraea alba*, 8 *N. perennans* and 1 *N. malicorticis*. The 13 isolates sent from Medford were identified as 9 *N. alba*, 3 *N. perennans* and 1 *N. malicorticis* (however, the N. malicorticis isolate was from an apple tree in Corvallis). The presence of *N. alba* had not been noted previously. The literature on *N. alba* indicates that it primarily lives as a saprophyte (surface feeding rather than infecting) on dead bark. This indication of the prevalence of *N. alba* will allow us to focus on the tree bark as a likely source of the fungus for fruit infection, and examine the fungus behavior and chemical sensitivity in that environment.

2. Various spring and pre-harvest spray programs were tested for control of bull's-eye rot during the 2000 growing season in a Bosc pear block that typically has a high level of infection. Spring sprays (targetted at scab) did not appear beneficial for bull's-eye rot control (Figure 1), but strobilurin fungicides (Flint and Sovran) were as effective as ziram when applied two weeks before harvest (Figure 2). (Flint has a pre-harvest interval of 14 days; the Sovran label currently indicates 30 days). These results suggest that using ziram earlier in the season followed by a strobilurin fungicide two weeks before harvest may be useful for protection of fruit against bull's-eye rot. This program is currently being evaluated.

3. We have tried to predict the amount of bull's-eye rot in pear fruit by freezing a sample of the fruit, then holding it at 50° F to speed up the development of the disease. The method has been successful with d'Anjou but not Bosc. In this study, we inoculated Bosc fruit with spores of the pathogen, then held half of the fruit at 50°F without freezing and half in air storage at 30° F, then compared the amount of decay that developed at each temperature. Bosc fruit inoculated with *Neofabraea perennans* developed similar incidence of bull's-eye rot in six weeks at 50° F as at 30° F in five months. It now appears possible to estimate the amount of infection that will occur in fruit lots in long term storage by holding samples at the warmer temperature. The study is being repeated again this year.

4. A postharvest Mertect drench controlled bull's-eye rot in Bosc fruit inoculated on the tree in June, August, or one week before harvest in September. Dithane, applied at any of four times from three weeks before inoculation to one week after inoculation, also controlled bull's-eye rot in fruit inoculated in June. Flint, Ziram, and Thiram application before or after inoculation did not control bull's-eye rot at any of the three inoculations.

5. Preliminary results of monthly inoculations of wounded pear bark with *N. perennans* indicate that pear wood may only be susceptible from September through April; inoculations from May through August have not resulted in canker development. Cankers resulting from inoculations in October through February developed acervuli (spore-producing structures). Later inoculations through the spring produced fewer acervuli. Spore production on cankers appears to be highest from the end of August until mid-October.

Fig. 1. Effect of Spring Treatments on Bull's-Eye Rot

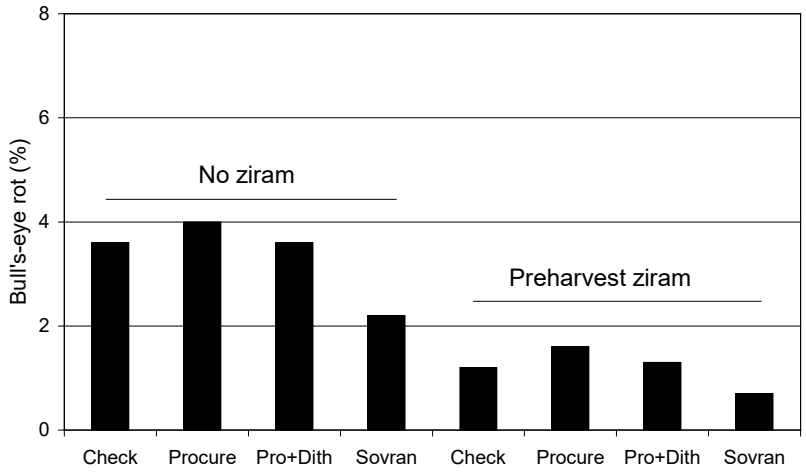
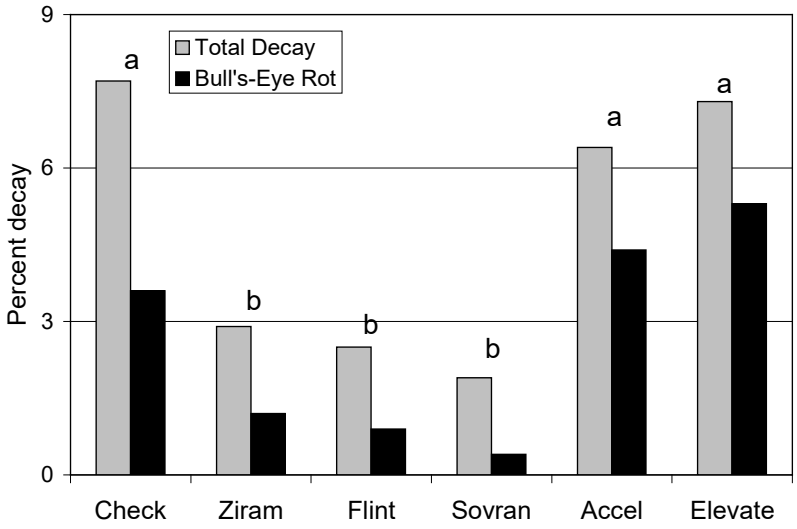


Fig. 2. Effect of Preharvest Sprays on Postharvest Decay



Justification for Proposed Research: Growers in Washington and Oregon periodically suffer from severe outbreaks of bull's-eye rot in stored pears. In part, this project arose from the frustration of the project leaders in attempting to control bull's-eye rot in pear fruit. Although we have conducted many spray trials, there is a sense of "shooting in the dark" without a more fundamental knowledge of the cycle of events which describe this disease. This project has linked scientists at OSU and a graduate student at OSU working on the bull's-eye rot problem with scientists in Canada who have recently made important progress in understanding perennial canker disease in apple, and have developed molecular techniques for precise identification of fungus species involved in cankers and fruit rots.

Budget Requested for 2002-2003:

Item	Amount
Salaries and Wages	14,849
Services and Supplies	18,500 (see note below)
Travel	800
Total	34,149

note on Services and Supplies:

12,000 materials and support labor in BC
4,500 services and supplies at Medford
2,000 services and supplies at Hood River

Estimated Duration: 2 years.

Procedures: In apple, the fruit rot is associated with perennial cankers which develop on the tree limbs. However, in pear such cankers do not appear. Thus one of the key experimental objectives is to identify the source or sources of spores for fruit infections. One of the few facts we know about the disease in pear is that fruit can become infected on the tree during the growing season, without showing symptoms of decay from these orchard infections until after several months of cold storage. This project will attempt to determine where spores for fruit infection are coming from, and when and under what conditions fruit infections take place. If there is a tree phase to the disease in pear, what is the nature of the tree phase, and when do key events take place? We will need to confidently identify the species of fungi causing fruit rot and (if present) tree infections in pear growing districts in Washington and Oregon. As the above information is being developed, control measures targeted at vulnerable points in the disease cycle will be evaluated. Appropriate aspects of this research will be conducted in the orchards and laboratories of SOREC in Medford, MCAREC in Hood River, Simon Fraser Univesity in B.C., and Agri-Food Canada in Ottowa.

The principal areas of focus in this project will be:

1. Determine the species identity of fungi causing bull's-eye rot and (if present) tree infections in pear, in the Medford, Hood River, Yakima, and Wenatchee pear growing districts of Oregon and Washington. This will involve both classical laboratory techniques and precise molecular methods recently developed in Canada.

2. Assess the timing of infection of pear trees leading to development of anthracnose cankers under field conditions. Determine whether or not wounding is necessary for infection. Assess the timing of infection of pear fruit through a series of bagging experiments allowing fruit to be exposed for specific periods through the growing season.

3. We have begun a series of monthly wound inoculations of pear trees, using cultures derived from bull's-eye rot lesions as sources of inoculum. The development of cankers from these inoculations, and the production of spores on them will be followed through re-culturing of canker tissue and periodic washes to determine spore production and release. Previously, we found no infection of pear branches by spores produced in laboratory culture and placed in tubes on unwounds branches, but have seen some canker development from wound inoculations with mycelium.

4. Laboratory assessment of sensitivity of selected isolates of bull's-eye rot fungi from OR, WA and BC to selected fungicides for control and anthracnose cankers of pear and apple. Field assessment of efficacy of two fungicides (probably thiram and a copper product chosen on the basis of the laboratory assessments) for preventing infections leading to the development of anthracnose cankers on pear and apple, using potted clonal pear an apple rootstocks. Copper sprays have been listed among control recommendations for bull's-eye rot and tree infections, without clear evidence for their effectiveness or the appropriate timing of their application. Field evaluation of fungicides, including copper, are needed to clarify this situation.

CONTINUING PROJECT **YEAR 2/3**

PROJECT TITLE: Biology and Management of Pear Pests

PI: David Horton
USDA-ARS, Yakima Agric. Research Lab., Wapato, WA

COOPERATORS: E. Miliczky, T. Unruh, A. Moldenke, D. Granatstein

OBJECTIVES:
2001. **Project 1. Effects of mowing frequency on biological control (partial funding by SARE).** Finish quantifying and identifying soil organisms in each mowing treatment (with A. Moldenke; completed). Prepare extension bulletin summarizing the total project (to be completed this spring with D. Granatstein). Obtain more data on codling moth parasitism, using sentinel strips (this objective was attempted on 3 occasions during the summer, but birds destroyed 100% of strips each trial; study discontinued). **Project 2. Determine composition of insect communities on various cover crops.** This project is partially completed. **Project 3. Determine suitability of various pest insects as prey for *Campylomma*.** This study is partially completed. **Project 4. Conduct studies on overwintering biology of predatory arthropods.** Determine when predators emerge from overwintering sites in late winter and early spring (partial completion). Document numbers and types of arthropods overwintering in orchards as function of pest densities and spray programs (with T. Unruh; ongoing). Determine importance of mullein as overwintering host of predators and pests (completed). **Project 5. Determine role of non-orchard habitats as source of natural enemies and pests** (with G. Miliczky; partial funding by IFAFS; ongoing).

2002. Objectives in year 2002 will include several of those above. **(1) Mowing study.** Finish statistical analyses of soil insect data. Complete extension bulletin with D. Granatstein. **(2) Cover crops.** Determine numbers and species composition of predators and pests associating with various commercially available cover crops. Record effectiveness of each crop in preventing growth of weeds. Monitor phenology (germination, flowering, seed) of each crop, and relate to seasonal changes in insect communities. **(3). *Campylomma*.** Monitor *Campylomma* feeding and development rates on various pest taxa. **(4). Predator overwintering and emergence.** Confirm emergence phenology model developed last year by repeating the study this year. Complete study (with Unruh) correlating overwintering densities of predatory arthropods with spray programs and pest pressures. **(5). Alternative habitats**. Assist G. Miliczky with IFAFS study on role of alternative habitats affecting pest and predator numbers in orchards.

SIGNIFICANT FINDINGS:

- **Mowing study.** Almost 23,000 soil arthropods were collected from soil samples taken in mowing study. Data summaries and statistical tests are still being done. General trends were for predatory arthropods to increase in density with decreased mowing frequency. Densities of all organisms much higher in vegetated aisles than in the vegetation-free zones beneath trees.
- **Cover crops.** Sweep net samples were taken from 16 cover crops on 2 dates in May and June. Plots were unfortunately destroyed by late June storm, so no summer data available. There were large differences in the numbers and types of insects associated with the different crops. Grains and grasses tended to have lowest diversity. Vetch, mustard, lupine, and alfalfa with large numbers of predators, but also large numbers of *Lygus*.
- ***Campylomma.*** Determined feeding rates and developmental rate of *Campylomma* that were fed eggs of pear psylla.

- **Overwintering biology.** *(1)* Determined phenology of spring emergence for 3 predator and 1 pest species expressed as function of accumulated degree-days. *(2)* Documented numbers and types of predators overwintering in 27 pear orchards; will obtain (from T. Unruh) season-long beat-tray counts and spray records for each orchard, to determine whether pest pressures and insecticide decisions affect overwintering densities of predators in orchards; *(3)* Determined numbers and types of arthropods overwintering on mullein.
- **Non-orchard habitats.** Assisted G. Miliczky in determining types and numbers of arthropods associated with native plants growing adjacent to orchards. Results summarized at apple review.

METHODS (2002):
(1) Mowing study. Write extension bulletin with D. Granatstein summarizing effects of mowing frequency on densities of pests and predators in the soil, ground cover, and tree, and summarize effects of mowing on parasitism rates of leafminer, pear psylla, and codling moth.

(2). Cover crops. Approximately 20 cover crops including various grains (*Triticale*, wheat, rye, oats) and broadleaf plants (varieties of peas, vetch, alfalfa, mustard, lupine, insectary mixes) will be planted in early May at the Moxee farm; several of the fall varieties are already in the ground. Plots are 10 m x 10 m squares, laid out in a randomized block design with 3 replicates. Plots are sampled using sweep nets; samples are extracted using Berlese funnels. Samples will be taken once per month between May and October, providing data on phenology for the different insects. I will also record date of germination, flowering, and seeding, and provide a qualitative judgement about how effective each crop is in suppressing weed germination and growth. Seeds for each cover crop have been donated by Pro-Gene (Othello).

(3). *Campylomma*. I now have *Campylomma* in continuous culture. Standard feeding and development trials will be conducted using the following prey: European red mite; grape mealybug; pear psylla nymphs; flower thrips (tentative); green peach aphid. I will record consumption rates and development times for specific *Campylomma* life stages.

(4). Overwintering biology and emergence. Trees at 25 pear orchards were banded with cardboard in late August 2001 to act as overwintering shelters. Bands will be collected in mid-December and moved to a screened building at the Moxee farm. Bands will be placed in ventilated containers, and the containers will be checked at 2-3 day intervals beginning in late January for emergence of pests and predators. Temperature data will be simultaneously monitored. These data will be used to confirm a degree-day emergence model developed last year using these same methods. Densities of predators in the bands will be compared among orchards in combination with spray records and beat tray counts of pests (from T. Unruh) to determine whether we can discover orchard factors affect overwintering densities of natural enemies.

(5). Alternative habitats. Will assist G. Miliczky with sampling non-orchard habitats (report presented at apple review).

RESULTS AND DISCUSSION (2001):
(1). Mowing study. Plots were established at 3 orchards in summer 2000; plots differed in how frequently they were mowed. Soil arthropods were collected from each plot by taking round soil plugs (2.5 inches thick x 6 inches diameter). Insects were extracted from the plugs in Berlese funnels. We recovered and identified over 25,000 arthropods. The arthropods were grouped according to feeding guild: predator, fungivore, herbivore, scavenger. Predatory insects, spiders, and centipedes decreased in abundance in the soil as mowing frequency increased; predatory mites showed the

opposite trend. Densities of all soil arthropods very low in vegetation-free zone beneath trees. The data are still being quantified for statistical analysis.

(2). Cover crops. Nine cover crops had grown enough that I was able to sample them in both May and June (many had been fall-planted); an additional 6 crops (spring-planted) were sampled only in June. Table 1 presents sweep net data for these crops. The most abundant predators were *Orius* (minute pirate bug) and *Geocoris* (big-eyed bug), both common in orchards (*Geocoris* generally restricted to orchard floor, however). The latter species reached especially high densities in mustard, both vetches, alfalfa, and the lupines (all are legumes except the mustard). Minute pirate bugs were abundant in vetch 1, mustard, and alfalfa. The grains (*Triticale*, wheat rye, oats) tended to have lower numbers of predators than the broad-leaf plants, although the peas also generally had low numbers. The most common pests were *Lygus* (*hesperus* and *elisus*) (on mustard, vetch, lupine) and western flower thrips (all crops, although identifications need to be confirmed; we recorded only presence/absence for thrips). The project is being repeated this year to get season-long data for the different insect taxa.

(3) *Campylomma*. The first study was done to obtain consumption and development rates for *Campylomma* fed eggs of pear psylla. From hatch to molt of new adults required 14.4 days at 23° C (Table 2). During this interval, *Campylomma* ingested an average of 246.8 eggs per predator. This study is ongoing and will determine ingestion rates on other pest species, as noted above.

(4) Overwintering biology and spring emergence of predators. *(1). Overwintering densities.* Cardboard bands were placed in 27 pear orchards to act as overwintering shelters for predators. Bands were collected in Decmber, and arthropods identified and counted. The data are being analyzed statistically at the moment. I will obtain season-long beat tray counts for each orchard and spray records for each orchard (both from T. Unruh) to determine whether pest pressures or insecticide pressures affect densities of predators overwintering in the orchard. *(2). Emergence from overwintering sites.* Overwintering insects were collected using cardboard bands from a number of orchards. Emergence from bands was monitored for 3 common predators and 1 pest (Fig. 1). Brown lacewings (*Hemerobius* sp.) emerged very early in late winter, while green lacewings (*Chrysopa nigricornis*) emerged very late; *Deraeocoris brevis* was intermediate. The test will be repeated this spring to determine adequacy of the degree-day relationship shown in Fig. 1. *(3). Arthropods overwintering on mullein.* I collected mullein plants in December from 11 sites in Yakima valley to determine numbers and types of pests and predators using these plants for overwintering. Over 40,000 arthropods were counted from the 55 plants (5 per site). Common predator taxa included western predatory mite, minute pirate bug, and spiders (Table 3). However, the plant is also an excellent source of flower thrips, spider mites, *Lygus*, and pear psylla (Table 3).

(5) Use of alternative habitats. The person hired on the present project assisted to some extent on the Miliczky/Horton IFAFS project. A full report was given at the apple review.

Table 1. Predatory and pest (Lygus) arthropods collected in cover crops. Entries indicate numbers per 30 sweeps. *, June sampled only; remaining species sampled in May and June (entries average the two dates). Cover crops having numbers associated with them (e.g., Pea 2, Pea 3), indicate different varieties.

	Mustard	Pea 2	Pea 3	Pea 4	Pea 5	Triticale 1	Triticale 2	Wheat	Vetch 1	Vetch 2*	Alfalfa*	Rye*	Oats*	Lupine 1*	Lupine 2*
Orius	11	2	2	4	0	1	9	4	22	2	10	0	0	5	4
Geocoris	57	0	0	0	1	1	1	2	96	26	15	21	1	48	31
Nabis	3	1	1	2	0	1	3	3	3	0	4	0	2	6	0
Coccinellidae	7	0	1	0	0	0	0	1	4	1	0	0	0	0	0
Syrphids	3	0	1	1	0	0	0	0	0	2	9	0	0	0	5
Lacewings	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Spiders	7	2	5	3	2	3	2	3	1	4	10	2	3	3	6
Parasitoids	22	1	3	3	1	2	3	1	34	5	20	0	0	0	3
Totals	110	6	13	13	4	8	19	14	161	40	68	23	6	62	49
Lygus	99	7	14	17	3	1	9	10	93	21	7	1	2	27	41

Table 2. Development and consumption rates of *Campylomma* fed eggs of pear psylla; n=20.

Instar	# days in instar	# eggs consumed per instar
I-II	5.4	59.4
III	2.5	46.8
IV	2.8	53.7
V	3.7	86.9
Totals	14.4	246.8

Summary

This project is a mix of studies having heavy emphasis on biological control: First, little is known about what species of insects associate with commercially available cover crops (at least for the Pacific northwest region), and studies begun here have attempted to correct this. The study indicates that insect communities differ substantially among different cover-crops. Second, I am trying to improve our understanding of the role of non-orchard native plant species as a source of natural enemies and pests. The large scale IFAFS project (with Miliczky) and the mullein study have both contributed to this effort, and show that certain pests and predators in orchards are common on certain host plants outside of the orchard. My study of mullein indicates that this plant species - - known to be an important source of pests and predators during the growing season - - is also a source of pests and predators in late winter and early spring, due to its suitability to many species as an overwintering host. Third, the SARE- and WPCC-funded mowing project showed that decreased mowing frequency leads to increased densities of predatory arthropods in the ground cover and in the upper soil surface. Fourth, I am learning more about the biology of natural enemies in pear orchards. I am very interested in *Campylomma*, as this predator appears increasingly to be one of the most valuable biological control agents in pear orchards. My studies showed that an individual insect can consume upwards of 240 psylla eggs during development; impact on other prey species merits attention. Lastly, the overwintering studies will help us determine what factors (specifically, insecticide program and pest pressure) affect densities of predators in orchards in late fall and winter; this information is useful, as the overwintering predators are the source of early-season biological control in orchards. The emergence study will assist us in understanding what species of predators might be most susceptible to dormant and delayed dormant applications of insecticides in pear orchards.

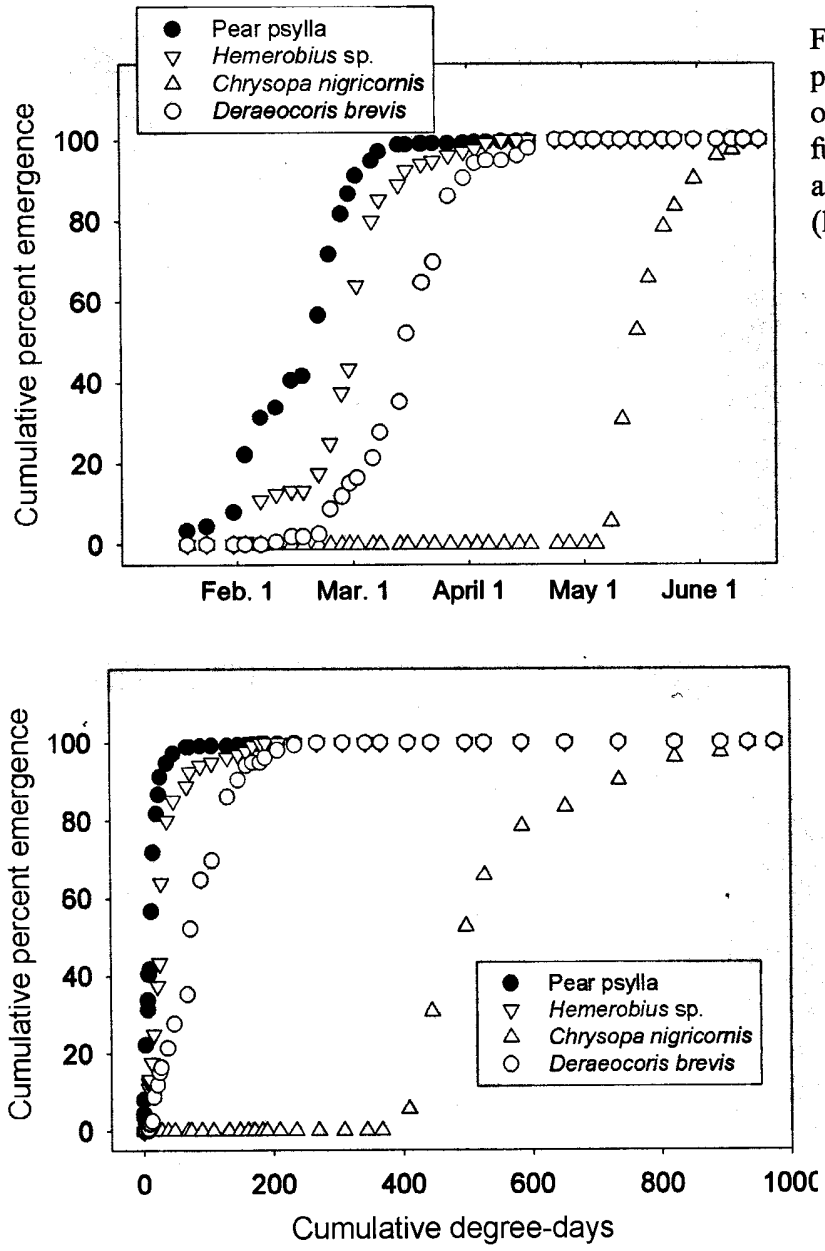


Figure 1. Emergence of 3 predators and 1 pest from overwintering shelters as function of date (upper graph) and accumulated degree-days (lower graph).

Table 3. Pest, predator, and parasitic taxa collected from mullein. Rosettes and stalks combined. Numbers indicate densities per 5 plants, averaged over the 11 collection sites. Numbers for Thysanoptera and Acari are estimates based upon subsamples taken from each complete sample.

PESTS	Acari[a] (mites)		Spider mites	□16
	Thysanoptera[a]	Thripidae	Western flower thrips	□340
	Homoptera	Psyllidae	Pear psylla	7.1
	Heteroptera	Miridae	*Lygus* spp.	11.1
		Pentatomidae	Unidentified stinkbugs	0.6
PREDATORS	Acari[a] (mites)	Phytoseiidae	Western predatory mites (+ related species)	□90
			Amblyseius spp.	□15
		Anystidae	Unidentified pred. mites	□30
	Heteroptera	Anthocoridae	Minute pirate bugs	14.9
			Xylocoris umbrinus	0.5
		Miridae	*Deraeocoris brevis*	0.4
		Lygaeidae	Big-eyed bugs	0.6
		Nabidae	Damsel bugs	0.09
		Reduviidae	Assassin bugs	0.09
	Coleoptera	Coccinellidae	Spider mite destroyers	0.2
			Other ladybug beetles	0.3
		Carabidae		0.2
		Staphylinidae		0.8
	Neuroptera	Hemerobiidae	Brown lacewings	0.5
	Diptera	Syrphidae	Hoverflies	0.1
	Hymenoptera	Sphecidae	Solitary wasps	0.1
	Araneae (spiders)	several families		9.9
	Chilopoda (centipedes)			0.1
PARASITOIDS	Diptera	Tachinidae		0.1
	Hymenoptera			3.9

[a] samples still being processed

BUDGET
Biology and Management of Pear Pests, David Horton
Project duration: 2001-2003, **Current year:** 2002

	Year 1 (2001)	**Year 2 (2002)**	Year 3 (2003)
Total	34,673	**30,050**	31,185

Current year breakdown:

	Year 1 (2001)	**Year 2 (2002)**	Year 3 (2003)
Salary	25,683	**22,260[a]**	23,100
Benefits	8990	**7790[b]**	8085

[a] Salary (0.75 FTE) for GS-6 technician; remaining 0.25 FTE provided by IFAFS; [b] 35%.

CONTINUING PROJECT **YEAR 2/3**

Project title: Integrated management of fire blight of pear and apple

PI: Kenneth B. Johnson
Organization: Dept. Botany & Plant Pathology, Oregon State University, Corvallis, OR
Co-PI(s)/affiliation(s): Virginia Stockwell (OSU, Corvallis)
Cooperator(s): David Sugar (OSU, Medford), Joyce Loper (USDA-ARS, Corvallis), Tim Smith (WSU, Wenatchee)

Objectives:
In 2001:

1. Evaluate new products for fire blight suppression (ongoing).
2. Field-test mixtures of beneficial bacteria optimized for compatibility of their biological mechanisms (ongoing).
3. Evaluate temperature forecasts as a predictor of fire blight risk (concluded).
4. Develop simple temperature-based models for prediction of growth rate of beneficial bacteria and of *Erwinia amylovora* in pear and apple blossoms (concluded).

Proposed In 2002:

1. Evaluate new products for fire blight suppression.
2. Field-test mixtures of beneficial bacteria optimized for compatibility of their biological mechanisms
3. (**New**) Evaluate potential for epiphytic growth of *Erwinia amylovora* on common flowers frequented by honey bees but which are not hosts of fire blight

Significant findings:

- Field trials were conducted to evaluate alternative products for suppression of blossom blight. For a third year, Myco-Sin (a stone powder) and Surround (kaolin clay) provided significant suppression of fire blight in a trial conducted in apple.
- For a third and concluding year, the accuracy of COUGARBLIGHT predictions based on 3 to 4 day temperature forecasts were compared to similar predictions based on daily data obtained from weather stations located within pear and apple production areas. Graphs of forecasted versus observed fire blight risk indicate that extended temperature forecasts of up to 3 to 4 days are valuable for improving the timing of chemical and biological products for fire blight suppression.
- Replicated growth chamber experiments were used to measure growth rates of selected bacterial strains on pear and apple blossoms at temperatures of: 43, 48, 54, 59 and 65 °F. Results demonstrated that in the range of 43 to 54°F, strains of beneficial bacteria have a competitive growth advantage over that of the fire blight pathogen. At 59 and 65°F, however, the growth rate of fire blight pathogen catches up to the benficail strains. In an unheated screenhouse, during periods of warm weather, growth rates of the fire blight pathogen were higher than those of beneficial bacteria.
- A decision aid that identifies periods favorable for the introduction of bacterial antagonists (or soft chemical products) into orchard environments was finalized. The decision utilizes two data sources: 1) strain-specific, bacterial growth/degree hour models, and 2) 4-day extended temperature forecasts provided by weather forecasting services.
- In a field trial on Bartlett pear, the combination of *Pseudomonas fluorescens* A506 mixed with the iron chelate, FeEDDHA, decreased the incidence of fire blight by 81% and was significantly superior to either A506 or FeEDDHA alone; in this study, streptomycin was 87% effective. In a trial conducted in Rome apple, the combination of one application of a mixture of *P. fluorescens* strain A506ecp- and *Pantoea agglomerans* strain C9-1 followed by

an application of FeEDDHA, resulted in a level of control numerically and statistically similar to that obtained with streptomycin.

Methods: Objective 1. New chemical and biological agents with potential to control fire blight were tested: Myco-Sin stone powder, Surround kaolin clay, host resistance inducers Messenger and Vacciplant, and several strains of beneficial bacteria. These experiments were conducted in a blocks of Bartlett and Bosc pear and Rome apple located in Corvallis, OR. [A trial also was conducted in a Bartlett pear block in Medford, but for a second fire blight failed to develop at this site.] In all trials, experimental treatments were arranged in randomized block designs with 4 to 6 replications of individual trees. Treatments included alternative products, a water-treated control and standard antibiotic products (streptomycin and oxytetracycline). Treatments were applied to near run-off at 30% and 80% bloom with a hand-directed backpack sprayers. Freeze-dried inoculum of the fire blight pathogen (strain *Ea*153nal, streptomycin sensitive) was applied near full bloom. Incidence of fire blight was evaluated by counting and removing individual diseased blossom clusters (strikes) on each tree.Outline the methods to be employed.

Objective 2. The iron-chelate FeEDDHA (Sequestrene 138) was selected, as it makes iron available to A506, but not the fire blight pathogen *Erwinia amylovora*. An experiment to assess iron bioavailability on blossoms of Snowdrift crabapple and Bartlett pear was conducted. A construct of A506 (A506 *pvd::inaZ*) was used to assess iron bioavailability on blossoms. This strain that carries a plasmid that has the gene for the ice nucleation protein following an iron-regulated promoter, which causes the gene to produce ice nuclei only when environmental concentrations of bioavailable iron are low. A506 *pvd::inaZ* was applied to blossoms suspended (1 X 10^8 CFU/ml) in water or in a solution of Sequestrene 138 (FeEDDHA) at a rate of 1 pound/100 gallons. At 58 h after inoculation, blossoms were harvested and were tested for ice nucleation activity at -5C by standard methods and spread on King's medium B containing rifampicin to estimate population sizes of the constructs. Field trials were conducted on mature Bartlett pear and Rome apple trees at the Botany and Plant Pathology Experimental Farm near Corvallis Oregon. Water, FeEDDHA (Sequestrene 138 at 1 pound/acre), A506 (1 X 10^8 CFU/ml), and a tank mix of Sequestrene 138 and A506 were applied to 5 replicate trees as described above.

Objective 3. Accuracy of extended temperature forecasts for prediction of 4-day degree-hour totals was evaluated for six apple/pear production areas in the Pacific Northwest: Rouge Valley in southwestern Oregon, Hood River Valley in north central Oregon, Walla Walla River Valley in northeastern Oregon, Yakima Valley south central Washington, Columbia Valley near Wenatchee in central Washington, and the Okanagon Valley in north central Washington. Historical records of daily minimum and maximum temperature were obtained from the Agrimet network (http://mac1.pn.usbr.gov/agrimet) and converted to daily degree hour estimates. Three and 4-day forecasts of daily minimum and maximum temperatures for each production region were obtained from commercial forecasting services. Forecasted temperature data were converted to estimates of daily degree hours with the algorithm shown above. Degree-hour values derived from actual and forecasted temperatures were plotted in graphical arrays as 4-day moving totals (which is the protocol for assessing fire blight risk with the COUGARBLIGHT model). Both COUGARBLIGHT degree hour sums (base 15.5°C) and degree hour sums with a r base temperature of 10°C were compared. The latter degree hour total was labeled the 'bacterial growth index', as 10°C reflected the lower limits for observation of bacterial growth on apple and apple blossoms (see screenhouse experiment).

Objective 4. In growth chambers, newly opened, detached pear or apple blossoms were placed into vials containing 10% sucrose and maintained in growth chambers set at temperatures of 6, 9, 12, 15 or 18°C for 4 days. Blossoms were spray inoculated with a bacterial strain (*P. fluorescens* A506, *P. agglomerans* C9-1, *E. amylovora* 153Nal). Population sizes of the bacterial strains were monitored on 3 blossoms sampled from each treatment every 24 to 48 h. The experiment was repeated six times in 2000 and eight times in 2001. In screen house experiments, Marked, newly-opened blossoms of a pear cultivar ('Aristocrat' or 'Bartlett') or of an apple cultivar ('Snowdrift' or 'Golden Delicious') were spray inoculated with suspensions of *P. fluorescens* A506, *P. agglomerans* C9-1, or *E. amylovora* 153Nal. Blossoms were sampled at the time of treatment and after (4 days). The cultivars were chosen to create a continuous bloom over the 6-week period, which allowed the

inoculation/96-hour incubation protocol to be repeated 9 times over the course of the experiment. Enclosing trees in plastic chambers, and heating the chamber with a 100-watt light bulb during the incubation period created an additional treatment. Ambient and chamber temperatures during each incubation period were monitored on with electronic temperature sensors. In both kinds of experiments, natural log transformations were applied to the population size data, and linear regression was used to calculate the intrinsic growth rate (proportional increase of bacterial population per hour) for each strain at each temperature. Computed growth rates were regresses on total degree hours over the 4-day period.

Results and discussion:

Objective 1. Trees used in the studies were large with 300-500 blossom clusters per tree. Compared to the water control, Bac-Master, Myco-Sin, Surround, *P. fluorescens* strain A506 plus FeEDDHA, and the combination of *P. fluorescens* strain A506 and *P. agglomerans* strain C9-1 plus FeEDDHA (but not with Messenger or Surround) resulted in significantly ($P \leq 0.05$) fewer diseased blossom clusters. Mean incidences of disease were statistically similar among water and the chemical agents, Messenger, VacciPlant, and CaCo3. No phytotoxic symptoms were observed on any of the treatments with the exception of some petal browning with CaCO3. The strain of *E. amylovora* (*Ea*153Nal) inoculated onto trees was sensitive to streptomycin, and thus, as expected, this antibiotic was effective in the experiments. The stone powder, Mycosin, is produced in Germany, and its status as a potential product for fire blight control in the U.S. is unclear. The results reported for beneficial bacteria are encouraging, but in pear trials we overwhelmed these treatments with very high levels of pathogen inoculum. We are currently working on several strategies to improve efficacy of these strains, and more results with beneficial bacterial are presented under objective 2.

Treatment and Rate/100 gal of water		Mean number of blighted blossom clusters/tree	
Water control		324	a*
Messenger	6.7 oz.	320	a
CaCO3	20 lb	266	ab
VacciPlant	30 fl oz.	254	ab
Surround	50 lb	191	bc
Ecp- plus	fresh		
*Pa*C9-1 plus	fresh		
Messenger	6.7 oz		
Then FeEDDHA 16 o		233	abc
Ecp- plus	fresh		
*Pa*C9-1plus	fresh		
then Surround plus	50 lb		
FeEDDHA	16 oz	220	abc
Ecp-	fresh		
then FeEDDHA	16 oz	174	bc
Ecp- plus	fresh		
*Pa*C9-1 plus	fresh		
FeEDDHA	16 oz	182	bc
Ecp- plus	fresh		
*Pa*C9-1	fresh		
then FeEDDHA	16 oz	138	c
Myco-Sin	8.3 lb	156	bc
Pace Bac-Master	29 oz	140	c

*Means followed by the same letter do not differ significantly according to Fischer's least significance difference at $P = 0.05$.

Objective 2. The ice nucleation activity of A506 (*pvd::inaZ*) on blossoms when applied in water was high, indicating that iron is present only in low concentrations on the stigmas and nectary of blossoms. The addition of iron as FeEDDHA significantly decreased the ice nucleation activity of A506 (*pvd::inaZ*) on blossoms, thus the addition of FeEDDHA significantly increased the

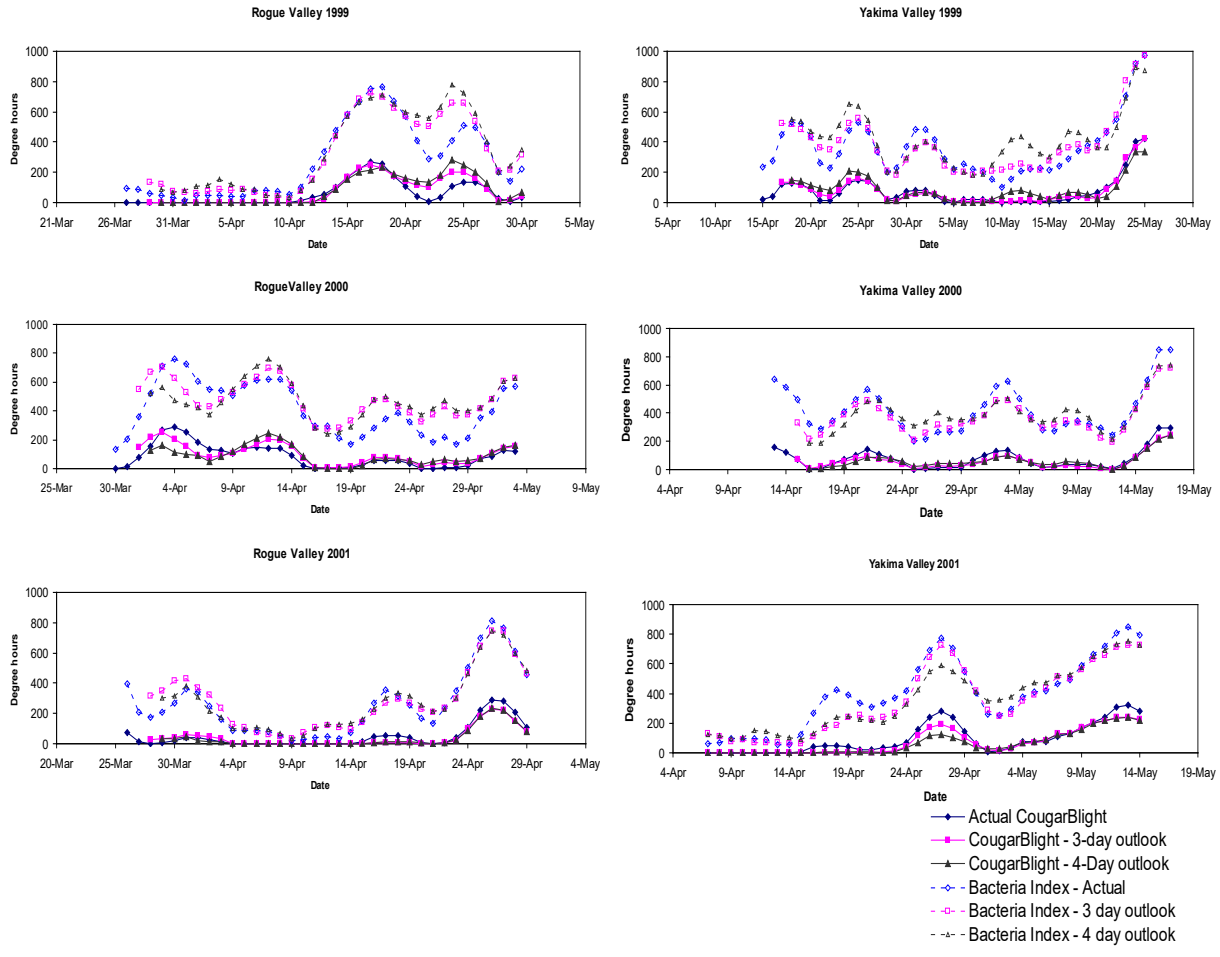
concentration of bioavailable iron to A506 on blossoms. Mean population size of A506 *pvd::inaZ* was not significantly affected by the addition of iron to the bacterial suspension at 58 h postinoculation.

The application of Sequestrene 138 or A506 alone had little effect on the incidence of fire blight compared to treatment with water. Combining A506 with Sequestrene 138 significantly decreased the incidence of fire blight compared to water-treated trees. In two trials, the level of control obtained with the combination of A506 and Sequestrene 138 was similar statistically to that obtained with streptomycin.

Table 1. Relative incidence of fire blight in two pear trials and one apple trial. Error! Bookmark not defined.

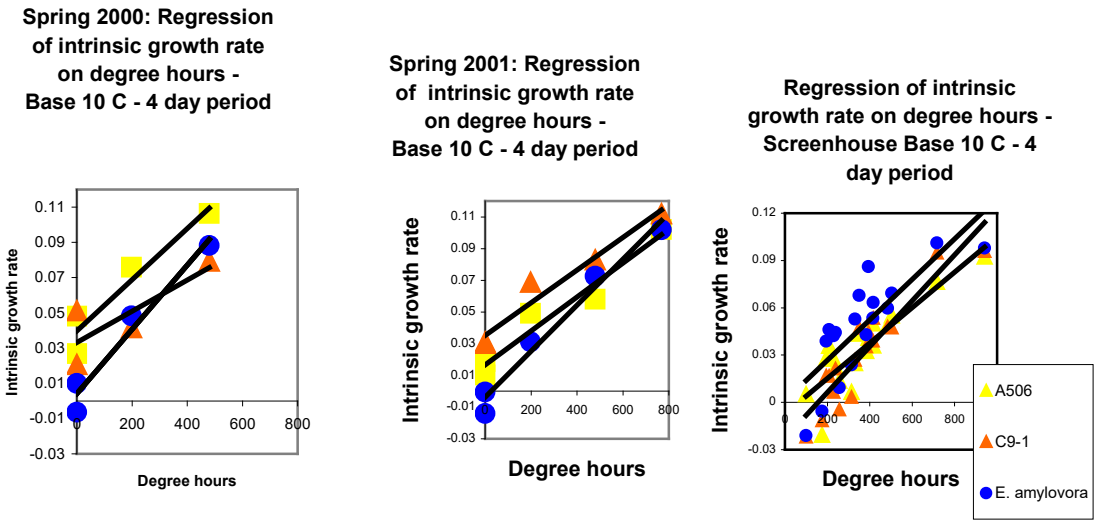
	Treatment					
Trial	Water	Sequestrene 138	Oxytetracycline	A506	A506 & Sequestrene 138	Streptomycin
Bart 1	100 A	101 A	74 A	66 A	19 B	13 B
Bart 2	100 A	69 AB	50 B	88 A	58 B	1 C
Rome	100 A				53 B	43 B

Different letters in the same row indicate a significant difference in disease incidence at $P = 0.05$.



Objective 3. Three- and 4-day temperature forecasts provided reasonably accurate estimates of expected degree hours that were consistent with actual degree hour data for multiple years and locations (Data for Medford and Yakima shown below. Data for other districts were similar.) Temperature is the most important indicator of fire blight risk. Forecasting models based on accumulated heat units are used widely to predict the buildup of large epiphytic populations of *E. amylovora* on floral surfaces. Thus, for a third season, we have found that temperature forecasts are sufficiently accurate to guide fire blight management decisions. The additional time provided by use of extended temperature forecasts could improve the timing of treatments, especially for "soft" products that need to be applied to before the pathogen has colonized a significant number of blossoms.

Objective 4. The goal of this objective was to develop a decision aid that will provide for optimal timings of bacterial antagonists into pear and apple orchards. This decision aid will further integrate the use of bacterial antagonists into conventional fire blight management strategies. Patterns of relative growth rates of specific bacterial strains as affected by temperature revealed that in the range of 43 to 54°F, the strains of beneficial bacteria, A506 and C9-1, have a competitive growth advantage over that of the fire blight pathogen. At 59°F, however, the fire blight pathogen had a higher growth rate than the beneficial strains (Figure 3). Significant, regression based degree-day models were developed that correlated populations size of A506 and C9-1 on pear and apple blossoms with accumulated degree hours above 8°C (47°F) (Figure 4). Screenhouse data indicate degree hour models with a base temperature of 10°C are appropriate for modeling growth rate of bacterial strains on blossom surfaces (i.e., model intercepts near zero). . Comparison of growth rates among beneficial bacteria and the pathogen provide insight as to orchard conditions most suitable for establishing beneficial bacteria in blossoms prior to significant colonization by the pathogen. A506 and C9-1 outgrow *E. amylovora* at temperatures in the range of 43 to 54°F, and thus are best established on blossoms prior to the beginning of a significant fire blight risk period. The degree hour regressions identified a lower threshold temperature for beneficial bacteria (~47°F), below which negligible growth occurred. The threshold temperatures, and degree-day models provide a basis for a decision aid patterned after COUGARBLIGHT, which used with extended weather forecasts can lead to optimal timings of introduction of beneficial bacteria for disease suppression. An example of a proposed decision matrix is presented below (note: the decision rules in the matrix pertaining to 'beneficial bacteria' require further validation).



A decision aid matrix designed to optimize timing of introductions of antagonistic bacteria into pear and apple orchards is proposed. Components within the matrix utilize the results of this study concerned with bacterial growth/degree hour relationships, and the values of expected degree hours derived from 3- and 4-day temperature forecasts.

Proposed decision matrix for timing introductions of antagonistic bacteria into pear and apple orchards

	Host Bloom Stage	Bacterial Growth Index	COUGARBLIGHT Model	
Timing of antagonist treatment		**Forecasted degree-hours above 50 °F**	**Timing of antagonistic bacteria relative to current fire blight risk episode**	
Ideal	25 to 90%	> 500 degree-hour expected in next 4 days	before episode begins to 200 degree-hour above 60°F	
Intermediate	to 500 degree-hour after full bloom	15 to 20% or expected in next 4 days	200 to 500 degree-hour above 60°F	200
Poor	very early, late, or 'rattail' bloom	< 200 degree-hour expected in next 4 days	> 500 degree-hour above 60°C	

Proposal for 2002:

Justification: The goals of our project are to understand to the biology and epidemiology of the fire blight pathogen, to develop and refine control methods for fire blight of pear and apple, and to integrate these technologies into commercial fire blight management. In recent years we have completed studies concerned with understanding how orchard environment affects growth and spread of bacteria on and among pear and apple blossoms. In addition, we have investigated and proposed a decision aid to modify fire blight forecasting models for use with softer control technologies. Our current activities include evaluating new chemical controls, and continuing to investigate, improve and optimize biological control of fire blight with beneficial bacterial. Our newest objective will be concerned with evaluating the potential for epiphytic growth of *Erwinia amylovora* on common, abundant flowers frequented by honeybees but which are not hosts of fire blight disease. To our knowledge, increase and growth of pathogen inoculum on common, abundant nonhost flowers (maple, willow, prunus, dandelion, mustard, clover, blackberry) has never been investigated. Knowledge of the potential for *Erwinia amylovora* to grow on flowers of nonhosts will provide further insight into seasonal dynamics of inoculum movement and availability, and will lead to improved indications as to when regional risks of fire blight epidemics are high.

Objectives:

1. Evaluate new products for fire blight suppression.
2. Field-test mixtures of beneficial bacteria optimized for compatibility of their biological mechanisms
3. **(New)** Evaluate potential for epiphytic growth of *Erwinia amylovora* on common flowers frequented by honey bees but which are not hosts of fire blight.

Objective 1 (onging): Evaluate new products for fire blight suppression. New chemical products with potential to control fire blight are being developed and tested (e.g. Starner (Oxynilic acid), Agri-gent (gentamycin sulfate), Messenger (harpin) , Vacciplant (algal derivative), Surround (kaolin clay), Mycosin (stone powder), Apogee (prohexidione-CA), Phyton 27 (copper in organic acid)). The mode

of fire blight suppression differs among these products. Our emphasis in testing new materials will be on effectiveness, compatibility with other control products, and potential side effects (e.g. blossom browning, russeting). These experiments will be conducted in blocks of pear and apple located in Corvallis, OR, with treatments repeated in Medford if trees are available. Experimental methods and data collection will be as described above under Objective 1.

Objective 2 (ongoing): Field-test mixtures of beneficial bacteria optimized for compatibility of their biological mechanisms. As a focal point of our research, we have collected a large volume of data showing that mixtures of bacterial antagonists on pear and apple blossoms are more effective than individual strains and, and perhaps more importantly, less variable in the degree of control obtained. Compared to individual strains, this reduced variability can be attributed to several factors including higher proportional colonization of host surfaces, apparent differential utilization of nutritional niches and differential optima in response to environmental stimuli. In our recent efforts, we have discovered several ways to enhance the efficacy antagonist mixtures. One of these enhancements involved selecting a mutant of *P. fluorescens* A506 deficient in an extracellular protease that degrades the herbicolin antibiotic produced by *Pantoea agglomerans*, resulting in conservation of the mechanism of antibiosis and a greater level of disease suppression. On another front, we have demonstrated that the addition of an iron chelate, FeEDDHA, to blossoms induces A506 to produce a previously unknown antibiotic, which also enhances disease suppression. **[The iron related work is the current subject of a USDA WR-IPM grant to Stockwell, Johnson, and Loper]**. On two other fronts, we have discovered strains of A506 that produce the antibiotic without the addition of exogenous iron, and we are beginning to investigate if the addition of avirulent (non-disease causing) strains of *Erwinia amylovora* to mixtures of beneficial bacteria enhances disease suppression. We are also working on ways to improve commercial formulations of gram-negative bacteria for cost effective delivery to the spray tank.

Thus, with multiple strategies for improved fire blight suppression with mixtures of beneficial bacteria, each year we attempt to evaluate these strategies in various combinations. Experimental methods and data collection will be as described above under Objective 2.

Objective 3 (New): Evaluate potential for epiphytic growth of *Erwinia amylovora* on common flowers frequented by honey bees but which are not hosts of fire blight.
Discussions on the development and control of the blossom blight phase of fire blight inevitably focus on the epiphytic growth of *E. amylovora* on floral structures, including stigmas and the hypanthium (nectary or floral cup). Stigmas, which are borne on the ends of the floral style, have been demonstrated to be the primary site epiphytic colonization by *E. amylovora* (1). Bees, and to a lesser extent other insects, are the primary vectors by which bacteria are introduced to stigmatic surfaces. Growth of *E. amylovora* on floral surfaces of important, rosaceous hosts of fire blight has been investigated widely, but the potential for *E. amylovora* to grow on surfaces of flowers that are not hosts of the disease has received little research effort. We believe of this kind of epiphytic growth may be significant in providing inoculum to pear and apple flowers during key periods in the bloom season, and thus, may be an important but little understood risk factor in the initiation of fire blight epidemics. For example, during key transition periods (e.g., from bloom of pear to apple, from low to high elevation, from primary to secondary rattail bloom), transport of the pathogen by honey bees to flowers of an abundant non-host (e.g., maple, alder, willow, or a cherry orchard) and back may provide an 'inoculum bridge' that increases the risk of fire blight in later blooming orchards. If this were the case, the knowledge would contribute to our ability to model and predict the availability of *E. amylovora* inoculum within a district.

The book *Plants for Beekeeping in Canada and the Northern United States* (2) provides top ten lists of the most important nectar or pollen sources for bees in the major eco-regions across the

continent. In the northwest, this list includes willow, maple, popular/alder, prunus, clover, dandelion, mustard, blackberry, broom, and rhododendron.

Methods: For this objective, we will collect flower-bearing branches of the above species. In growth chambers, bouquets of flowers will be inoculated with standardized suspensions of freeze-dried cells of *E. amylovora* strain 153Nal.. Population size of *Ea*153Nal will be monitored by dilution plating onto selective media. Population sizes among various flower types will be standardized on a per weight basis.

Literature Cited:

1. Johnson, K.B., and Stockwell, V.O. 1998. Management of fire blight: A case study in microbial ecology. Ann. Rev. Phytopathol. 36:227-248.
2. Ramsay, J. 1987. Pages 139-143 in: *Plants for Beekeeping in Canada and the Northern United States.* Intl. Bee Research Assoc., London.

Budget: Integrated management of fire blight of pear and apple;Kenneth B. Johnson
Proposed duration of objectives: Objectives 1 & 2: Ongoing; Objective 3: 2-3 years
Current year: 2002
Budget in 2001: $20,400 ($18,370 WPCC & $2,030 WTFRC)

Year	Last Year (2001)	**Year 2002**	Next year (2003)
Total	20,400	**16,100**	16,370

Budget specifics

Item	Last Year (2001)	**Current Request (2002)**	Next year (2003)
Salaries	10,000	**9,000**	9,180
Benefits (50%)	4,800	**4,500**	4,590
Wages	2,000		
Benefits (5%)	100		
Equipment			
Supplies	1,500	**1,000**	1000
Travel	800	**400**	400
Plot Maintenance	1,200	**1,200**	1,2000
Total	20,400	**16,100**	16,370

Salary is 2 months of a faculty research assistant

Support from other funding sources:
Oregon Agricultural Experiment Station
USDA Western Region IPM: 2000-2001, $150,000 (Stockwell's salary and support for iron/A506 research).
USDA (pending): 2002-2003, $156,000 (Stockwell's salary and research on avirulent *E. amylovora*).
Occasional grants-in-aid of research from chemical companies.

FINAL REPORT

Project title: Environmental Effects on Storage of Winter Pears

PI: Eric Curry, Plant Physiologist

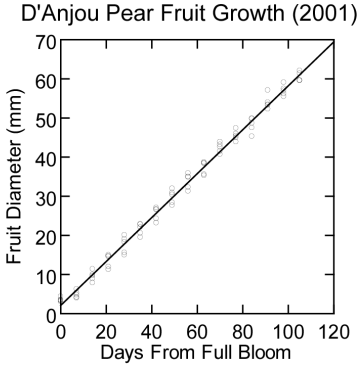
Organization: USDA, ARS, TFRL, Wenatchee, WA

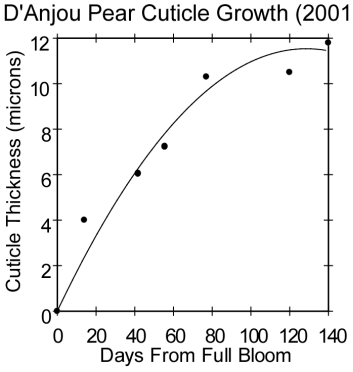
Objectives: There are complex interrelationships among climate, ripening, and the development of storage disorders, which, because they are not well understood, have resulted in incongruencies in reports of ripening behavior and scald development. This project is an attempt to better understand the influence of preharvest temperature on cuticle and wax development, fruit ripening potential, development of physiological disorders and their interrelationships by identifying effects of preharvest temperature on ripening behavior, fruit quality, storage disorders, cuticle development, wax accumulation, and antioxidant efficacy of 'd'Anjou' pears.

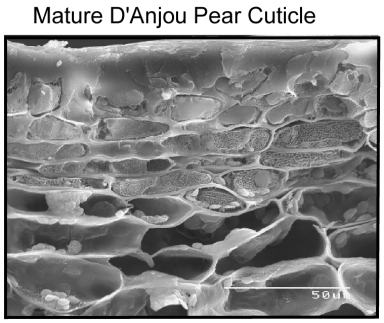
Results and Discussion:

Several studies were conducted this year. The first was to examine and measure development of the cuticle of pears growing at different elevations (microclimates). This was done both with light and electron microscopes.

As soon as the surface cells became exposed to dessication pressure, cuticle development began. This varied from location to location depending on weather conditions and loss of pubescence. It appeared early pubescence tended to delay cuticle development probably by increasing the relative humidity thereby reducing dessication pressure. As the fruit expanded and pubescence density decreased, exposure increased and wax development increased.





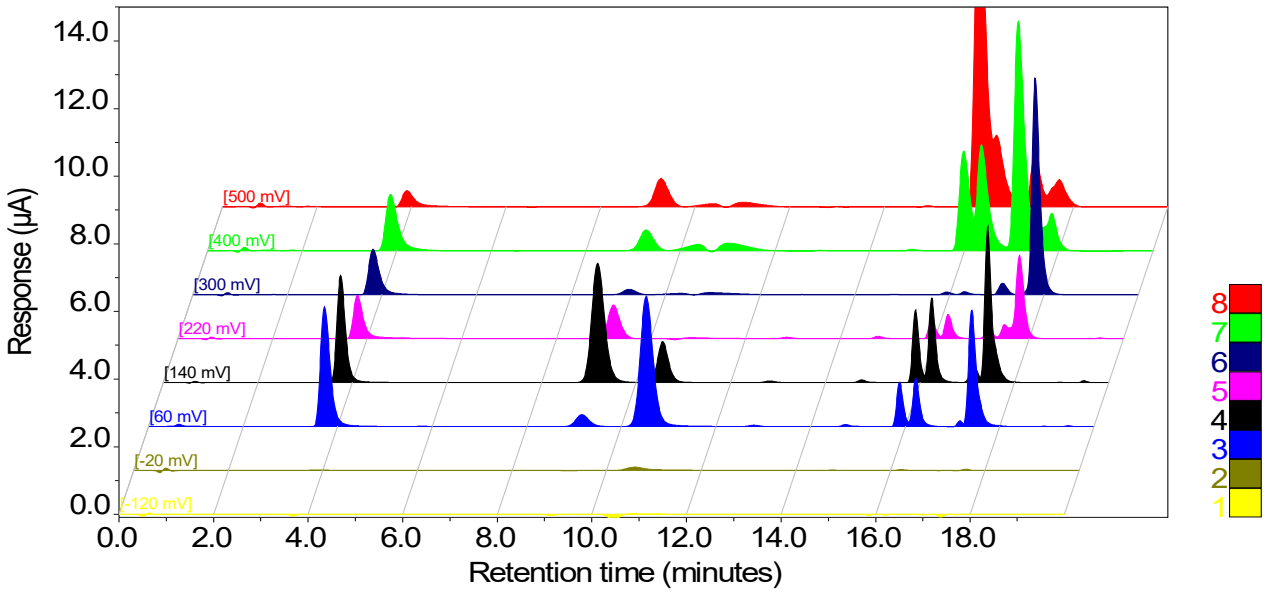


Mature d'Anjou pear fruit peel showing cuticle ranging in thickness from about 12 - 22 microns.

Wax ‘grows’ in the form of microtubules about 100-120 nm in diameter. These are composed of a number of compounds with a predominance of nonane and associated long chain carbon derivatives. These tubules, being ‘sticky’ to each other, associate into rows of tubules having the appearance of walls or platelets (similar to the walls of a log cabin). Cuticle development occurs by layered wax platelets. That is, the first wax plates to develop on the cell surface generally remain closest to the cell throughout fruit growth. As subsequent platelets develop, they meld and polymerize becoming an insoluble matrix of polyphenolic hydroxy esters. Platelets continue to develop on the surface of the previous layer which then polymerizes to the previous platelet. My theory is the microtubules are ‘attached’ to the epidermal cells throughout development of the wax and cuticle. Therefore, changes in environmental conditions such as temperature and light affect metabolism of the epidermal cells and therefore the composition of the wax and the subsequent cuticle. The antioxidants which are

most likely to have an impact on scald development are those which are closest to the cell, i.e., those formed early. However, epidermal cells both increase in size and number as long as fruit expansion continues. As seen in the figure above, the actively dividing cells are within the top 3-4 layers of cells, whereas beneath this, cells are mainly for storage of water, and soluble and insoluble carbohydrates. As cells divide and new cells form, triggered by expansion pressure from the internal cells, new microtubules form creating new areas of wax deposition and cuticle formation. As long as fruit growth occurs, new platelets will form, therefore, it seems the rate of expansion prior to harvest (and, therefore, the temperature, sunlight, and other factors contributing to fruit growth) is also an important key toward understanding the role of antioxidants in scald development in storage. For example, when the temperature prior to harvest is warm, the wax composition may be composed of longer chain hydrocarbons than when the temperature is cool. This will affect the composition of the cuticle developed during this particular period. In a similar fashion, the phenolic composition within this hydrocarbon matrix will also change depending on the temperature and the amount of light. Recall, that scald development both on pears and apples occurs predominantly on the shaded partion of the fruit. Solar radiation incident on the fruit surface triggers the cell to increase phenolics which can act as antioxidants against radicals generated during the photosynthetic energy conversions. Thus, high temperatures and low light levels before harvest due either to canopy shading or clouding would be the worse conditions for scald development. Understanding development of the cuticle is important in these respects.

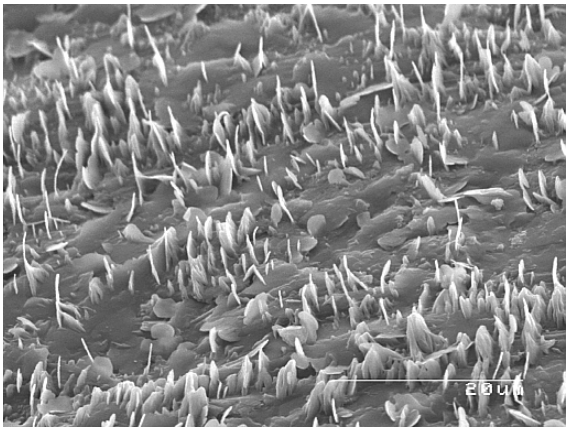
Samples were collected from the same 5 orchards used in the past, beginning at full bloom. Fruitlet samples were collected weekly for the first 6 weeks, bi-weekly for the next 6 weeks, and every three weeks thereafter. Hexane-soluble wax was extracted and examined qualitatively using UV absorbance at selected wavelengths. The samples were frozen at -80C and kept for further analysis. Because of delays in signing the federal budget, I was unable to acquire the equipment necessary to continue until recently. A photochemiluminescent detector is to be installed within the next two weeks which will enable measurement of total water soluble and lipd soluble antioxidants (in the form of free radical quenching). These will be compared with HPLC analysis of water-soluble phenolic antioxidants in samples throughout the growing period and during storage. The objective is to identify patterns in antioxidant extracts during fruit development that correspond to scald development in storage. This work continues.



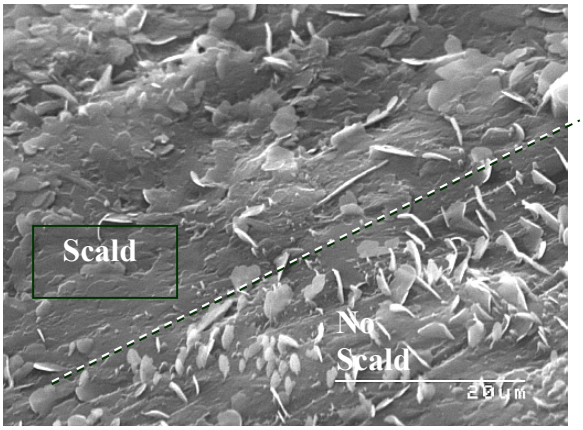
This Figure shows a typical chromatogram using an coulometric array of water soluble phenolics. Patterns from pear peel extracts from fruitlets through mature fruit will be examined using principal component analysis to determine correlations with scald development.

The second experiment was a continutation of the previous years work. The objective was to determine if quantity and quality of wax was related to the amount or retention of antioxidant applied to the fruit for scald control. We harvested samples from the 5 orchards used in the study, treated with either ethoxyquin or DPA for scald control, and placed fruit in regular and CA storage. At harvest and at 1, 2, 4, and 6 months in storage we extracted peel for wax analysis and for analysis of DPA and ethoxyquin. We initially ran into some snags related to co-elution. This could be resolved using different more selective detectors, however we hadn't the resources to acquire the necessary equipment or to outsource the samples for analysis. Thus, we had to use more extensive procedures to separate components. Analysis is close to completion.

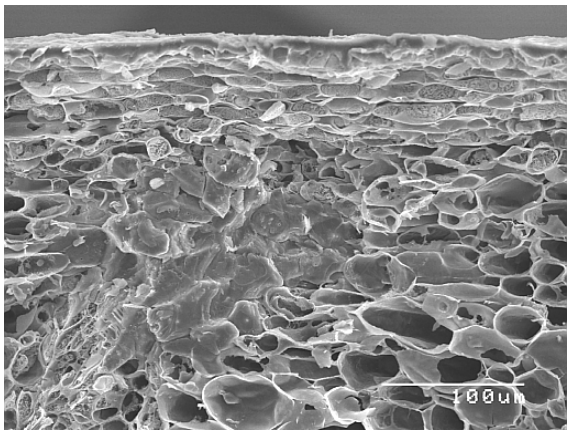
The third set of studies was to examine the nature of scald on the underlying tissue. That is, when scald appears, is the oxidation due to the cuticle itself, the layer of cells embedded in the cuticle, or subsequent underlying tissue. Samples of stored Anjou pears having areas of scald were used. Tissue with or without scald were excised and snap-frozen in liquid nitrogen. While frozen the tissue is shattered and freeze dried. This maintains the structural integrity of the fruit cells.



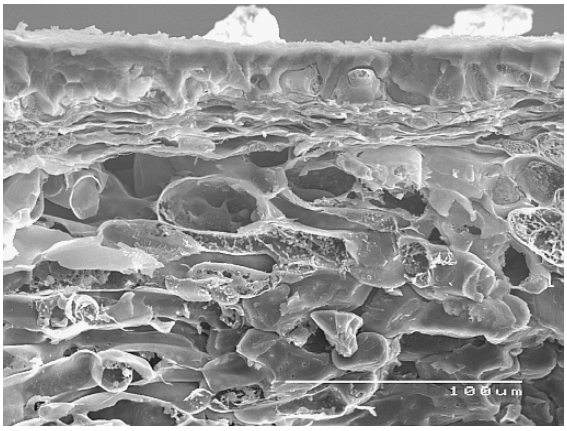
Anjou Peel Surface – 180 days RA – NO SCALD



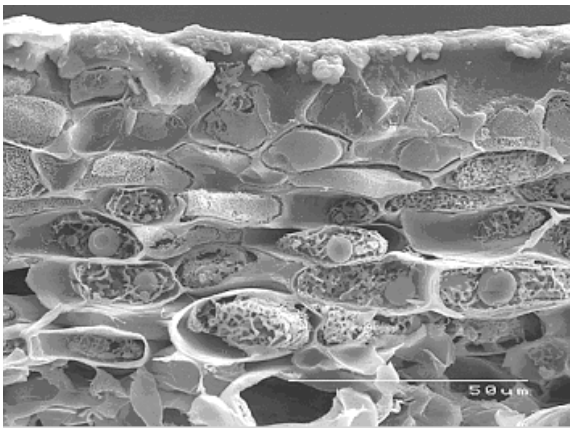
Anjou Peel Surface – 180 days RA – SCALD

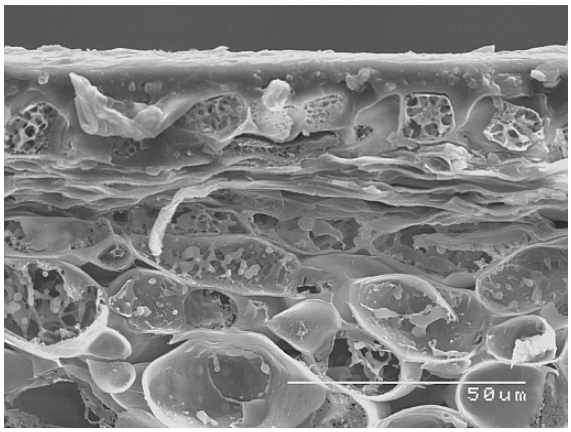


Anjou Peel Section – 180 days RA – NO SCALD



Anjou Peel Section – 180 days RA – SCALD





In the images above, several points are evident. The section of peel exhibiting scald (top right) shows a lack of actively growing platelets. This is reflected in the lack of integrity or collapse of the epidermal layers 2-4 (right middle and left bottom). Contrast this with those images on the left of

scald-free peel where platelets are actively growing and the sub-surface epidermal cells are expanded and intact. The appearance of scald apparently comes not from the cuticle which, when isolated and removed from the cellular tissue beneath, is clear and indistinct from that isolated from scalded peel, but rather from the collapse of tissue in layers 2-4 where phenolic compounds in the cell walls is oxidized and intensified.

This work is also continuing. We are in the process of examining the make up of cuticle isolates from scalded and normal fruit peel to determine if indeed the nature of the cuticle itself is changing (or changed). That is, is the cuticle part of the problem or an innocent bystander in scald development.

Budget:
Environmental Effects on Storage of Winter Pears
Eric Curry

Project duration: 1998 - 2001

Current year: 2001

Original budget request:

Year	1998	1999	2000	2001
Total	38,000	44,500	42,000	27,000

CONTINUING REPORT

Title: Postharvest Physiology of Winter Pears

Project Leader: Paul M. Chen

Cooperators: J. P. Mattheis; R. A. Spotts; S. R. Drake

Funding History:
Year Initiated: 1978
Funding in 2001-2002: $40,000

SIGNIFICANT FINDINGS:

1. To investigate the proper method for inducing the normal ripening capacity of MCP-treated 'd'Anjou' and 'Bartlett' pears after cold storage.

   'D'Anjou' pears harvested at optimum maturity with flesh firmness of 14 lbs (±0.5 lbs) were treated with 100 ppb and 300 ppb MCP within 2 days after harvest. Another group of untreated fruits were used as control. Both control and MCP-treated fruits were stored in air at -1°C. After monthly storage interval, control and MCP-treated fruits were ripened at 25°C with 500ppm ethylene for 7 days. Regardless of MCP dosage and storage length, MCP-treated 'd'Anjou' pears were incapable of ripening while control fruits ripened normally. It was concluded that the ripening environment enriched with 500ppm ethylene plus an elevated ripening temperature at 25°C could not overcome the effect of pre-storage treatment of MCP on inhibition of 'd'Anjou' pear ripening.

   'Bartlett' pears harvested at optimum maturity with flesh firmness of 18 lbs (±1.0 lbs) were treated with 100 ppb and 300 ppb MCP within 2 days after harvest. Another group of untreated fruits were used as control. Both control and MCP-treated fruits were stored in air at -1°C. After monthly storage interval, control and MCP-treated fruits were ripened at 25°C with 500ppm ethylene for 7 days. Regardless of MCP dosage and storage length, MCP-treated fruits were incapable of ripening while control fruits ripened normally. It was concluded that the ripening environment enriched with 500ppm ethylene plus an elevated ripening temperature at 25°C could not overcome the effect of pre-storage treatment of MCP on inhibition of 'Bartlett' pear ripening.

2. To investigate the efficacy of ethylene conditioning of under-chilled 'd'Anjou' pears during transporting period as influenced by different temperatures.

   The optimum temperature regimes for pre-conditioning 'd'Anjou' fruit in the transportation vehicle during the first two months of shipment were investigated. 'D'Anjou' pears were harvested at commercial maturity with flesh firmness (FF) of 14 lb (±1.0 lb) and held in cold storage at 30°F in air. After 0.5, 1.0, 1.5 and 2.0 months of storage, 'd'Anjou' fruit were conditioned at 45, 55 or 60°F in a simulated container enriched with 100ppm ethylene (±20 ppm) for 3 or 7 days. 'D'Anjou' stored for less than 0.5 month required a pre-conditioning temperature at 68F for a short-distance shipment (i.e., a 3-day shipment) in order to induce the swift ripening capacity at the retail markets. For the safest in-transit pre-conditioning operation, the pre-conditioning temperature at 45°F was the best for a long-

distance shipment (i.e., a 7-day shipment) while the pre-conditioning temperature at 60°F was the best for a short-distance shipment during the first two months of marketing season.

3. To develop innovative procedures and packaging design for "Fresh-Cut" 'd'Anjou' Pears to form an artful, healthy and nutritious meal.

The proper ripeness of 'd'Anjou' pears (*Pyrus communis*, L.) for "Fresh-cut" use was established at the stage when the flesh firmness (FF) decreased to between 7.0 lb (3.2 kg) and 5.0 lb (2.3 kg) in a ripening environment enriched with 100 ppm ($mg \cdot L^{-1}$) ethylene at 68 °F (20 °C). A fruit sectionizer was used to slice each pear into 8 wedges. To prevent the cut surface of each fruit wedge exposing to air during slicing, three slicing methods were evaluated. The method of 'Pouring Anti-browning Solution onto Incision' was found to be the easiest and most convenient cutting procedure without allowing the fruit to make direct contact to air during manual cutting. Different concentrations of a mixture of L-ascorbic acid (Vitamin C) and potassium chloride (KCl) were evaluated for the anti-browning effect without affecting the taste of the Fresh-Cut fruit wedges and injuring the cut surface. An anti-browning solution with 10% L-ascorbic acid (Vitamin C) and 2% potassium chloride (KCl) (pH 2.321) was the most suitable for anti-browning without any undesirable effects to the Fresh-Cut fruit wedges. A dipping time of 30 seconds was sufficient to maintain the fruit wedges with little browning discoloration for 14 days at shelf temperatures of 30°F (-1 °C) or 35°F (3 °C). A prototype of a 1.6-pint transparent plastic container was designed with eight compartments for fruit wedges sliced from an individual pear by a commercially available fruit sectionizer. The container is user-friendly and makes it very easy and quick for packaging. Eight fruit wedges cut from an individual fruit are arranged in the container to form a pretty lotus flower shape. A scoop of shredded cheese or cottage cheese or yogurt can be added to the center of the arrangement and topped with a red color maraschino cherry to form an artful, healthy and nutritious meal.

OBJECTIVES:

1. To investigate the proper method for inducing the normal ripening capacity of MCP-treated 'd'Anjou' and 'Bartlett' pears after cold storage.

2. To investigate the efficacy of ethylene conditioning of under-chilled 'd'Anjou' pears during transporting period as influenced by different temperatures.

3. To develop innovative procedures and packaging design for "Fresh-Cut" 'd'Anjou' Pears to form an artful, healthy and nutritious meal.

PROCEDURES:

Objective 1. To investigate the proper method for inducing the normal ripening capacity of MCP-treated 'd'Anjou' and 'Bartlett' pears after cold storage.

'Bartlett' pears were harvested at commercial maturity with flesh firmness (FF) of 17.5 lb (±0.5 lb) on August 18, 2001. Harvested fruits were transferred into 40-lb wooden boxes with polyethylene liner. After 24 hours of harvest, fifteen boxes of 'Bartlett' pears were transferred into a gas-tight CA room and treated with 100 ppb MCP for 24 hours at 68°F. Treated fruits were then transferred into an air cold storage at30°F. Another fifteen boxes of untreated fruits were also transferred the same cold storage. The final fifteen boxes of 'Bartlett' pears were also transferred into the gas-tight CA room and treated with 300 ppb MCP for 24 hours at 68°F. Treated fruits were also transferred into the same air cold storage at 30°F. After 1, 2, 3, 4 and 5 months of storage, fruits treated with 100 ppb MCP, 300 ppb MCP and control untreated fruits were removed from the cold

storage and put in **a room enriched with 500ppm ethylene at 78°F**. On day 1, 3, 5 and 7 of ripening, changes in flesh firmness (FF), extractable juice (EJ), titratable acids (TA) and soluble solids content (SSC) were determined.

'D'Anjou' pears were harvested at commercial maturity with FF of 13.5 lb (±0.5 lb) on September 7, 2001. Harvested fruits were transferred into 40-lb wooden boxes with polyethylene liner. After 24 hours of harvest, fifteen boxes of 'Bartlett' pears were transferred into a gas-tight CA room and treated with 100 ppb MCP for 24 hours at 68°F. Treated fruits were then transferred into an air cold storage at30°F. Another fifteen boxes of untreated fruits were also transferred the same cold storage. The final fifteen boxes of 'd'Anjou' pears were also transferred into the gas-tight CA room and treated with 300 ppb MCP for 24 hours at 68°F. Treated fruits were also transferred into the same air cold storage at 30°F. After 1, 2, 3, 4 and 5 months of storage, fruits treated with 100 ppb MCP, 300 ppb MCP and control untreated fruits were removed from the cold storage and put in **a room enriched with 500ppm ethylene at 78°F**. On day 1, 3, 5 and 7 of ripening, changes in flesh firmness (FF), extractable juice (EJ), titratable acids (TA) and soluble solids content (SSC) were determined.

Objective 2. To investigate the efficacy of ethylene conditioning of under-chilled 'd'Anjou' pears during transporting period as influenced by different temperatures.

'D'Anjou' pears were harvested at commercial maturity with flesh firmness (FF) of 14 lb (±1.0 lb) from an orchard block at Mid-Columbia Agricultural Research and Extension Center, Hood River, Oregon. Harvested fruit were transferred into cardboard boxes (44 lb/box) with polyethylene liners and held in cold storage at 30°F in air.

After 0.5, 1.0, 1.5 and 2.0 months of storage, 6 boxes of fruit were conditioned at 45, 55 or 60F in a simulated container enriched with 100 ppm ethylene (±20 ppm) for 3 or 7 days. The concentration of ethylene in the pre-conditioning container was set at 100 ppm. After the end of 3 or 7 days of in-transit pre-conditioning treatments, treated fruit were transferred into a cold storage at 32F for 7 days to simulate the holding period at the terminal (distributing) point. Treated fruit were then placed in an ethylene-free room at 68F to simulate the ripening activities on the shelf in the retail markets. Changes in flesh firmness (FF) of the treated fruit (10 fruits per replicate) were determined on day 1, 3, 5 and 7 of ripening at 68°F. FF with the unit of lb per square inch force of each pared punch was read directly from the gauge of the UC pressure tester. Two FF readings of each fruit were averaged. The means of FF from 3 replicates were used to determine the fruit-softening pattern at each ripening interval. The natural logarithmic function, which is a monotonically decreasing regression, was found to be better fit for most of the data than the exponential function with an asymptote-approaching zero. Therefore, the natural logarithmic function was applied to fit all the fruit softening curves.

Objective 3. To develop innovative procedures and packaging design for "Fresh-Cut" 'd'Anjou' Pears to form an artful, healthy and nutritious meal.

Identification of the proper ripeness of 'd'Anjou' pears for "Fresh-Cut". To establish the proper ripeness for Fresh-Cut, 6 boxes of commercially packed 'd'Anjou' pears (with uniform size of 90 fruits per a 44-lb box) were purchased from Duckwall–Pooley Fruit Company, Odell, Oregon on 13 April 2001. These fruits had been previously pre-sized and stored in a controlled atmosphere (CA) storage. The detailed CA condition was not disclosed due to the Company's policy. Packed boxes of 'd'Anjou' fruits were placed into a ripening room enriched with 100ppm ($mg \cdot L^{-1}$) ethylene at 68 °F (20 °C) for 10 days at the Mid-Columbia Agricultural Research and Extension Center, Hood River, Oregon. Two boxes of fruit constituted one replicate and were randomly labeled as replicate #1, #2 and #3. At each daily ripening interval, 10 fruits from each replicate (5 fruits from each box) were

considered as an experimental unit and used for the determination of changes in flesh firmness (FF), extractable juice (EJ), soluble solids (SS), titratable acids (TA) and dessert quality for 10 days. When fruits ripened to the proper ripeness with an acceptable dessert quality (i.e., the quality rating of 5 or higher), 20 fruits per each replicate were transferred into two separate holding rooms in air at 30 °F (-1°C) and 35 °F (2 °C) respectively for 7 and 14 days to determine the extended shelf life of 'd'Anjou' fruits at this stage of ripening. After each holding period, 10 fruits (as an experimental unit) per replicate were used for the determination of FF, EJ, SS and TA.

Development of anti-browning solutions. Different concentrations of the mixture of L-ascorbic acid (Vitamin C) (Fisher Scientific, Inc., Fair Lawn, New Jersey, U.S.A.) and potassium chloride (KCl) (Sigma Chemical Co., St. Louis, Missouri, U.S.A.) were evaluated for the anti-browning effect without affecting the taste of the Fresh-Cut wedge and injuring the cut surface. Color photographs of pear wedges immediately after treatment (day 0) and after 14 days of holding in air at 30 °F were used to confirm the visual assessment.

Development of Fresh-Cut procedures. 'D'Anjou' fruits softened to the proper ripeness with an acceptable dessert quality were used for the Fresh-Cut experiments. A fruit sectionizer (EKCO Housewares, Inc., Franklin, Illinois, U.S.A.) was used to slice each pear into 8 wedges. To prevent the cut surface of each wedge from being exposed to air during slicing, three slicing methods were evaluated. These 3 methods were: i) Inverse cutting method; ii) Submerged cutting method; and iii) Pouring anti-browning solution onto incision method.

Determination of the shelf life of Fresh-Cut ripened 'd'Anjou' slices. Three boxes of commercially packed 'd'Anjou' pears (size 90) also were purchased from Duckwall-Pooley Fruit Company, Odell, Oregon on 13 April 2001. Packed fruits were temporarily held in air at 30 °F for 14 days and then placed into a ripening room enriched with 100ppm ethylene at 68 °F. Ten fruits (as an experimental unit) from each box were used for the determination of FF and dessert quality daily. When the fruit softened to the proper ripeness with an acceptable quality (the quality rating of 5 or above) for fresh-cut purpose, the third cutting method (pouring anti-browning solution onto incision method) was used for cutting the ripened fruit. Sliced fruit wedges were retained in anti-browning solution for 30 seconds. Each of 8 fruit wedges was separately arranged at an upright position in a 1.6-pint transparent plastic. Eight fruit wedges were arranged separately to form a lotus-flower shape in the container. The container was covered with a lid perforated with a hole (1/8-inch or 0.32-cm in diameter). Ten containers with fruit wedges were kept in two separate holding rooms at 30 °F and 35 °F in air respectively. After 7 and 14 days of holding at each temperature, five containers from each room were assessed for browning discoloration and dessert quality of fruit wedges.

Container design for Fresh-Cut 'd'Anjou' slices. A prototype of a 1.6-pt (0.8-L) transparent plastic container was designed to have 8 compartments that house 8 fruit wedges sliced from an individual pear by a commercially available fruit sectionizer.

RESULTS AND DISCUSSION:

Objective 1. To investigate the proper method for inducing the normal ripening capacity of MCP-treated 'd'Anjou' and 'Bartlett' pears after cold storage.

'D'Anjou' pears harvested at optimum maturity with flesh firmness of 14 lbs (±0.5 lbs) were treated with 100 ppb and 300 ppb MCP within 2 days after harvest. Another group of untreated fruits were used as control. Both control and MCP-treated fruits were stored in air at -1°C. After monthly storage interval, control and MCP-treated fruits were ripened at 25°C with 500ppm ethylene for 7 days. Regardless of MCP dosage and storage length, MCP-treated 'd'Anjou' pears were incapable of ripening while control fruits ripened normally. MCP-treated fruits did not softened during 7 days of ripening while control fruits softened normally to 3 lbs or less on day 7 at 25°C plus 500 ppm ethylene after 1, 2 and 3 months of storage intervals. It was concluded that the ripening environment

enriched with 500ppm ethylene plus an elevated ripening temperature at 25°C could not overcome the effect of pre-storage treatment of MCP on inhibition of 'd'Anjou' pear ripening.

'Bartlett' pears harvested at optimum maturity with flesh firmness of 18 lbs (±1.0 lbs) were treated with 100 ppb and 300 ppb MCP within 2 days after harvest. Another group of untreated fruits were used as control. Both control and MCP-treated fruits were stored in air at -1°C. After monthly storage interval, control and MCP-treated fruits were ripened at 25°C with 500ppm ethylene for 7 days. Regardless of MCP dosage and storage length, MCP-treated fruits were incapable of ripening while control fruit ripened normally. MCP-treated fruits did not softened during 7 days of ripening while control fruits softened normally to 3 lbs or less on day 7 at 25°C plus 500 ppm ethylene after 1, 2, 3, 4 and 5 months of storage intervals. It was concluded that the ripening environment enriched with 500ppm ethylene plus an elevated ripening temperature at 25°C could not overcome the effect of pre-storage treatment of MCP on inhibition of 'Bartlett' pear ripening.

Objective 2. To investigate the efficacy of ethylene conditioning of under-chilled 'd'Anjou' pears during transporting period as influenced by different temperatures.

The optimum temperature regimes for pre-conditioning 'd'Anjou' fruit in the transportation vehicle during the first two months of shipment were investigated. 'D'Anjou' pears were harvested at commercial maturity with flesh firmness (FF) of 14 lb (±1.0 lb) and held in cold storage at 30°F in air. After 0.5, 1.0, 1.5 and 2.0 months of storage, 'd'Anjou' fruit were conditioned at 45, 55 or 60F in a simulated container enriched with 100ppm ethylene (±20 ppm) for 3 or 7 days.

Two important criteria must be considered for pre-conditioning 'd'Anjou' pears in transit. First, pre-conditioned fruit should remain firm with no risk of bruising in transit and during distributing to the retail markets. Second, pre-conditioned fruit should be able to ripen swiftly with desirable dessert quality on the shelf in the retail markets within a few days (preferably no longer than 5 days). The previous study has shown that 'd'Anjou' pears softened to 6 lb develop juicy texture with acceptable flavor during ripening at 68F. In this study, the successful in-transit preconditioning treatment of 'd'Anjou' pears was set at the prerequisite condition that the flesh firmness of pre-conditioned fruit must be no less than 9 lb on day 1 of ripening at 68F and no more than 6 lb on day 5 of ripening at 68F. This prerequisite condition would allow the retailers to handle the partially ripened 'd'Anjou' fruit without risk of bruising damage while the consumers can enjoy the fully ripe fruit shortly after purchasing.

Assuming it requires 3 days for a short-distance shipment from the shipping point (i.e., the packing house) to the terminal distributing point and 7 days for a long-distance shipment. At the in-transit temperature of 45F, regardless of storage interval, 'd'Anjou' fruit could meet the prerequisite condition for a long-distance shipment but only the fruit stored for 2 months could meet the prerequisite condition for a short-distance shipment. Fruit stored for less than 2 months could not soften to a proper ripeness within 5 days at 68F after 3-day in-transit pre-conditioning treatment.

At the in-transit temperature of 55F, 'd'Anjou' fruit stored for 0.5 or 1.0 month could meet the prerequisite condition for a long-distance shipment (i.e., 7-day in-transit pre-conditioning treatment) and again only the fruit stored for 2 months could be pre-conditioned in transit for a short-distance shipment (i.e., 3-day in-transit pre-conditioning treatment). Fruit stored for 1.5 and 2.0 months softened to less than 8 lb after 7-day in-transit pre-conditioning treatment and became a risk of bruising during handling. Fruit stored for 0.5 or 1.0 month were not capable of softening to 6 lb on day 7 of ripening at 68F after 3-day in-transit pre-conditioning treatment.

At the in-transit temperature of 60F, 'd'Anjou' fruit stored for 1 month or longer could be

successfully pre-conditioned for a short-distance shipment (i.e., 3-day in-transit pre-conditioning treatment). Fruit stored for 0.5 month required 7 days of ripening at 68F to soften to 6 lb if they were conditioned for 3 days in transit as a short-distance shipment. Regardless of storage intervals, 'd'Anjou' fruit had softened to less than 9 lb on day 1 at 68F and thus became too soft to be handled safely in the retail markets after a long distance shipment (i.e., 7-day in-transit pre-conditioning treatment) regardless of storage intervals.

It was clear that 'd'Anjou' stored for less than 0.5 month might require a pre-conditioning temperature at 68F for a short-distance shipment in order to meet the prerequisite condition. For the safest in-transit pre-conditioning operation, the pre-conditioning temperature at 45F was the best for a long distance shipment while the pre-conditioning temperature at 60F was the best for a short distance shipment.

Objective 3. To develop innovative procedures and packaging design for "Fresh-Cut" 'd'Anjou' Pears to form an artful, healthy and nutritious meal.

Our results demonstrated that the proper ripeness of 'd'Anjou' fruitsfor "Fresh-cut" use was established at the stage when the flesh firmness (FF) decreased to between 7.0 lb (3.2 kg) and 5.0 lb (2.3 kg) in a ripening environment enriched with 100ppm ($mg \cdot L^{-1}$) ethylene at 68 °F (20 °C). To prevent the cut surface of each fruit wedge exposing to air during slicing, three slicing methods were evaluated. The method of 'Pouring Anti-browning Solution onto Incision' was found to be the easiest and most convenient cutting procedure without allowing the fruit to make direct contact to air during manual cutting. Different concentrations of a mixture of L-ascorbic acid (Vitamin C) and potassium chloride (KCl) were evaluated for the anti-browning effect without affecting the taste of the Fresh-Cut fruit wedges and injuring the cut surface. An anti-browning solution with 10% L-ascorbic acid (Vitamin C) and 2% potassium chloride (KCl) (pH 2.321) was the most suitable for anti-browning without any undesirable effects to the Fresh-Cut fruit wedges. A dipping time of 30 seconds was sufficient to maintain the fruit wedges with little browning discoloration for 14 days at shelf temperatures of 30°F (-1 °C) or 35°F (3 °C). A prototype of a 1.6-pint transparent plastic container was designed with eight compartments for fruit wedges sliced from an individual pear by a commercially available fruit sectionizer. The container is user-friendly and makes it very easy and quick for packaging. Eight fruit wedges cut from an individual fruit are arranged in the container to form a pretty lotus flower shape. A scoop of shredded cheese or cottage cheese or yogurt can be added to the center of the arrangement and topped with a red color maraschino cherry to form an artful, healthy and nutritious meal.

PROPOSAL - CONTINUING PROJECT

Title: Postharvest Physiology of Winter Pears

Project Leader: Paul M. Chen

Cooperators: R. A. Spotts; J. P. Mattheis; S. R. Drake

Funding History:
Year Initiated: 1978
Funding in 2001-2002: $40,000
Funding requested for 2002-2003: $59,313

SIGNIFICANT FINDINGS:

1. To investigate the proper method for inducing the normal ripening capacity of MCP-treated 'd'Anjou' and 'Bartlett' pears after cold storage.

   'D'Anjou' pears harvested at optimum maturity with flesh firmness of 14 lbs (±0.5 lbs) were treated with 100 ppb and 300 ppb MCP within 2 days after harvest. Another group of untreated fruits were used as control. Both control and MCP-treated fruits were stored in air at -1°C. After monthly storage interval, control and MCP-treated fruits were ripened at 25°C with 500ppm ethylene for 7 days. Regardless of MCP dosage and storage length, MCP-treated 'd'Anjou' pears were incapable of ripening while control fruits ripened normally. It was concluded that the ripening environment enriched with 500ppm ethylene plus an elevated ripening temperature at 25°C could not overcome the effect of pre-storage treatment of MCP on inhibition of 'd'Anjou' pear ripening.

   'Bartlett' pears harvested at optimum maturity with flesh firmness of 18 lbs (±1.0 lbs) were treated with 100 ppb and 300 ppb MCP within 2 days after harvest. Another group of untreated fruits were used as control. Both control and MCP-treated fruits were stored in air at -1°C. After monthly storage interval, control and MCP-treated fruits were ripened at 25°C with 500ppm ethylene for 7 days. Regardless of MCP dosage and storage length, MCP-treated were incapable of ripening while control fruit ripened normally. It was concluded that the ripening environment enriched with 500ppm ethylene plus an elevated ripening temperature at 25°C could not overcome the effect of pre-storage treatment of MCP on inhibition of 'Bartlett' pear ripening.

2. To investigate the efficacy of ethylene conditioning of under-chilled 'd'Anjou' pears during transporting period as influenced by different temperatures.

   The optimum temperature regimes for pre-conditioning 'd'Anjou' fruit in the transportation vehicle during the first two months of shipment were investigated. 'D'Anjou' pears were harvested at commercial maturity with flesh firmness (FF) of 14 lb (±1.0 lb) and held in cold storage at 30°F in air. After 0.5, 1.0, 1.5 and 2.0 months of storage, 'd'Anjou' fruit were conditioned at 45, 55 or 60°F in a simulated container enriched with 100ppm ethylene (±20 ppm) for 3 or 7 days. 'D'Anjou' stored for less than 0.5 month required a pre-conditioning temperature at 68F for a short-distance shipment (i.e., a 3-day shipment) in order to induce the swift ripening capacity at the retail markets. For the safest in-transit pre-conditioning operation, the pre-conditioning temperature at 45°F was the best for a long-

distance shipment (i.e., a 7-day shipment) while the pre-conditioning temperature at 60°F was the best for a short-distance shipment during the first two months of marketing season.

3. To develop innovative procedures and packaging design for "Fresh-Cut" 'd'Anjou' Pears to form an artful, healthy and nutritious meal.

The proper ripeness of 'd'Anjou' pears (*Pyrus communis*, L.) for "Fresh-cut" use was established at the stage when the flesh firmness (FF) decreased to between 7.0 lb (3.2 kg) and 5.0 lb (2.3 kg) in a ripening environment enriched with 100 ppm ($mg \cdot L^{-1}$) ethylene at 68 °F (20 °C). A fruit sectionizer was used to slice each pear into 8 wedges. To prevent the cut surface of each fruit wedge exposing to air during slicing, three slicing methods were evaluated. The method of 'Pouring Anti-browning Solution onto Incision' was found to be the easiest and most convenient cutting procedure without allowing the fruit to make direct contact to air during manual cutting. Different concentrations of a mixture of L-ascorbic acid (Vitamin C) and potassium chloride (KCl) were evaluated for the anti-browning effect without affecting the taste of the Fresh-Cut fruit wedges and injuring the cut surface. An anti-browning solution with 10% L-ascorbic acid (Vitamin C) and 2% potassium chloride (KCl) (pH 2.321) was the most suitable for anti-browning without any undesirable effects to the Fresh-Cut fruit wedges. A dipping time of 30 seconds was sufficient to maintain the fruit wedges with little browning discoloration for 14 days at shelf temperatures of 30°F (-1 °C) or 35°F (3 °C). A prototype of a 1.6-pint transparent plastic container was designed with eight compartments for fruit wedges sliced from an individual pear by a commercially available fruit sectionizer. The container is user-friendly and makes it very easy and quick for packaging. Eight fruit wedges cut from an individual fruit are arranged in the container to form a pretty lotus flower shape. A scoop of shredded cheese or cottage cheese or yogurt can be added to the center of the arrangement and topped with a red color maraschino cherry to form an artful, healthy and nutritious meal.

OBJECTIVES:

1. To investigate the fruit maturity of 'd'Anjou' pears in relation to the dessert qualities and shelf-life of "Fresh-Cut" slices during early marketing season.

2. To investigate the effect of ripening temperatures and ethylene concentrations on the uniformity of ripeness of under-chilled 'd'Anjou' pears for "Fresh-Cut" purpose.

3. To develop innovative procedures for freeze-drying fruit bits of 'd'Anjou' Pears as "value-added" commodities.

4. To investigate fruit properties and eating qualities of 'd'Anjou' pears during monthly intervals at the retail shelf.

5. To extend the marketability of 'd'Anjou' pears by combination of MCP and ethylene treatment and its relationship to storage decays.

PROCEDURES:

Objective 1. To investigate the fruit maturity of 'd'Anjou' pears in relation to the dessert qualities and shelf-life of "Fresh-Cut" slices during early marketing season.

'D'Anjou' pears will be harvested weekly beginning at the commercial maturity with flesh firmness (FF) of 15.0 lb (±0.5 lb) for 5 weekly intervals until FF declines to about 11.0 lb in 2002 season. Harvested fruits will be transferred into 40-lb wooden boxes with polyethylene liner and

stored in air at 30°F. One week after the last harvest interval, 'd'Anjou' fruits with different maturations will be ripened in a ripening room enriched with 100ppm ethylene at 68°F. On day 5 and 7 of ripening, ripened fruits will be used for fresh-cut. The fresh-cut 'd'Anjou' fruit slices will be stored in plastic containers at 35°F. On day 1, 7 and 14 of holding, dessert qualities of fresh-cut 'd'Anjou' slices will be assessed. After 4, 6 and 8 weeks of the last harvest interval, d'Anjou' fruits with different maturations will be ripened in a ripening room enriched with 100ppm ethylene at 68°F. On day 5 and 7 of ripening, ripened fruits will be used for fresh-cut. The fresh-cut 'd'Anjou' fruit slices will be stored in plastic containers at 35°F. On day 1, 7 and 14 of holding, dessert qualities of fresh-cut 'd'Anjou' slices will be assessed.

Objective 2. To investigate the effect of ripening temperatures and ethylene concentrations on the uniformity of ripeness of under-chilled 'd'Anjou' pears for "Fresh-Cut" purpose.

'D'Anjou' pears will be harvested weekly beginning at the commercial maturity with flesh firmness (FF) of 15.0 lb (±0.5 lb) for 5 weekly intervals until FF declines to about 11.0 lb in 2002 season. Harvested fruits will be transferred into 40-lb wooden boxes with polyethylene liner and stored in air at 30°F. After 2, 4, 6, 8 and 10 weeks of the last harvest, fruits with different maturations will be removed from the cold storage and put in three separate rooms. **One room enriched with 500ppm ethylene at 78°F, another room enriched with 500ppm ethylene at 68°F and the third room without ethylene (<0.01ppm) at 68°F**. On day 1, 3, 5 and 7 of ripening, changes in flesh firmness (FF), extractable juice (EJ), titratable acids (TA) and soluble solids content (SSC) were determined. The uniformity of ripeness of 'd'Anjou' pears will be evaluated by the distribution of FF at each ripening interval at different ripening environments.

Objective 3. To develop innovative procedures for freeze-drying fruit bits of 'd'Anjou' Pears as "value-added" commodities.

'D'Anjou' pears with cull grade will be purchased from Duckwall–Pooley Fruit Company, Odell, Oregon monthly for 5 months in 2001. At each monthly interval, cull-grade 'd'Anjou' fruits will be placed into a ripening room enriched with 100ppm ($mg \cdot L^{-1}$) ethylene at 68 °F (20 °C) for 7 days at the Mid-Columbia Agricultural Research and Extension Center, Hood River, Oregon. On day 1 and 7 of ripening, 10 fruits from each replicate will be used for the determination of changes in flesh firmness (FF), extractable juice (EJ), soluble solids (SS), titratable acids (TA) and dessert qualities. Another 5 fruits will be used for cutting into approximately 0.25"x0.25"x0.05" size cubs (bits) and the cubes will be subjected to vacuum infiltration of food-grade anti-oxidant solution. After vacuum infiltration treatment, the fruit cubes will be freeze-dried. The eating quality of freeze-dried fruit bits will be assessed by the panelists.

Objective 4. To investigate fruit properties and eating qualities of 'd'Anjou' pears during monthly intervals at the retail shelf.

'D'Anjou' pears will be obtained monthly from five retail markets located around Portland area at the beginning of commercial marketing season in 2002 until the end of the 2002-2003 season. At each sampling interval, 60 fruits from each retail market will be purchased and ripened in an ethylene-free room at 68 °F at Mid-Columbia Agricultural Research and Extension Center. On day 1 and day 7 of ripening, fruit properties including flesh firmness (FF), extractable juice (EJ), titratable acids (TA) and soluble solids (SS) of 'd'Anjou' fruits will be determined. On day 1 and day 7 of ripening, eating qualities including texture, aroma, and flavor of 'd'Anjou' pears will also be assessed.

At each sampling interval, fruit temperature on the retail shelf and source of 'd'Anjou' fruits including grower's number and block number will be recorded.

Objective 5. To extend the marketability of 'd'Anjou' pears by combination of MCP and ethylene treatment and its relationship to storage decays.

'D'Anjou' pears will be harvested at the commercial maturity with flesh firmness (FF) of 14.5 lb (±0.5 lb). Harvested fruits will be transferred into 40-lb wooden boxes with polyethylene liner within 2 days of harvest. Packed fruits will be pre-conditioned in a ripening room enriched with 100ppm ethylene for 24 hours, 48 hours, and 72 hours at 68°F. Ethylene-preconditioned fruits will then be treated with 10 ppb MCP at 68°F for 24 hours. Treated fruits will be stored in air at 30°F. After 1, 2, 3, 4 and 5 months of storage, treated fruits will be ripened in an ethylene-free room at 68°F. After day 1 and day 7 of ripening, fruit properties including FF, EJ, TA and SS will be evaluated. On day 7 of ripening, the incidence of superficial scald disorder will also be assessed.

One group of ethylene/MCP treated fruits will be provided to Dr. R.A. Spotts for the study of storage decays.

ESTIMATED DURATION: 1 year

BUDGET REQUESTED:

ITEM	AMOUNT
Salaries and Wages	$33,086
OPE (43%)	$14,227
Service and Supplies	$11,000
Travel	$1,000
TOTAL	$59,313

CONTINUING REPORT

Title: Storage Decay Research

Project Leader: David Sugar, Professor
OSU, Southern Oregon Research & Extension Center

Cooperator: R.A. Spotts

Funding History: Year Initiated: 1983-84; funding in 2001-02: 20,000

Objective: The goal of this research is to develop a storage decay control program for winter pears in which diverse, independent decay control practices contribute to dependable reduction of postharvest diseases.

Significant Findings:
1. Several new materials can be used for pear flotation without injury provided that solution temperatures are low and exposure time is brief.

2. Decay control by SOPP is affected by the flotation material. While SOPP activity may be increased by a lower pH environment, decay control does not consistently correlate to pH.

The following studies are in progress:

3. Sequential orchard spray programs for decay control.

4. Use patterns for Scholar fungicide: drench vs. linespray, combinations with biocontrol.

5. Optimum temperatures for biocontrol treatments.

6. New fungicide and fungicide-biocontrol studies.

Results and Discussion:
1. Materials used for pear flotation can influence the phytotoxicity of SOPP. This can be associated with pH, since the more phytotoxic form of SOPP increased with lowering of pH. However, there are exceptions to the pH association, as has been found with lignosite. Furthermore, the phytotoxicity was found to be highly influenced by the temperature of the flotation solution (Tables 1-5).
2. Flotation materials influenced decay control in solutions containing SOPP (Table 6). As with phytotoxicity, there appears to be a partial but inconsistent association with solution pH. In some cases, it may be possible to reduced the SOPP concentration if the solution pH allows greater SOPP activity.

Table 1. Injury (phytotoxicity) rating on Comice pears floated in various solutions at specific gravity 1.05 in combination with 1% Steri-Seal (Steri-Seal is 22.6% SOPP). All fruit were thoroughly rinsed with fresh water following flotation for the indicated length of time. Temperature ranges indicate solution temperatures during flotation. All fruit were maintained at ~32 F before and after flotation. All pears had been previously commercially treated and packed in Chile. Experiments conducted in June, 2001.

Injury rating: 0= none, 1= slight, 2 = moderate, 3= severe

	Injury rating at **60-65 F**					
	Flotation time (min.)					
	5	15	20	30	45	60
1. Xeda F ("pH 9 formulation")		2		3	3	3
2. Soda ash (sodium carbonate)	2		2			3
3. K-Float (potassium carbonate)		0		0	0	2[a]
4. 50% molasses	0		3			3
5. Calcium chloride	2		3			3

	Injury rating at **45-50 F**			
	Flotation time (min.)			
	15	30	45	60
1. Xeda F ("pH 9 formulation")	1	2	3	3
2. Soda ash (sodium carbonate)	0	0	1[a]	2[a]
3. K-Float (potassium carbonate)	0	0	0	2[a]
4. 50% molasses	0	2	3	3
5. Calcium chloride	0	0	0	0

[a] darkened lenticels only

Table 2. Injury (phytotoxicity) rating on Oregon Comice pears floated in various solutions at specific gravity 1.05 in combination with Steri-Seal. All fruit were thoroughly rinsed with fresh water following flotation for the indicated length of time. Temperature ranges indicate solution temperatures during flotation. All fruit were maintained at ~32 F before and after flotation. November-December 2001.

Injury rating: 0= none, 1= slight, 2 = moderate, 3= severe

	Flotation temperature and time (min.)							
	35-40 F				**55-60 F**			
	15	30	45	60	15	30	45	60
1. Water	0	0	0	0	0	0	0	0
2. Water + Steri-Seal 0.5 %	0	0	0	0	0	0	0	0
3. Water + Steri-Seal 1%	0	0	0	0	0	0	0	0
4. Sodium carbonate	0	0	0	0	0	0	0	0
5. Sodium carb. + SS 0.5%	0	0	0	0	0	0	0	0
6. Sodium carb. + SS 1%	0	0	0	0	0	0	0	0
7. Potassium carb.	0	0	0	0	0	0	0	0
8. Potassium carb. + SS 0.5%	0	0	0	0	0	0	0	0
9. Potassium carb. + SS 1%	0	0	0	0	0	0	0	2[a]
10. Lignosite	0	0	0	0	0	0	0	0
11. Lignosite + SS 1%	0	0	0	0	0	0	0	0
12. Lignosite + SS 0.5%	0	0	0	0	0	0	0	0
13. Xeda F ("pH 10.6 formulation")	0	0	0	0	0	0	0	0
14. Xeda F + SS 0.5%	0	0	0	0	0	0	2	3
15. Xeda F + SS 1%	0	0	0	0	0	0	2	3
16. Calcium chloride	0	0	0	0	0	0	0	0
17. Calcium chloride + SS 0.5%	0	0	0	0	0	0	2	3
18. Calcium chloride + SS 1%	0	0	0	0	1	1	3	3
19. Sodium sulfate	0	0	0	0	0	0	0	0
20. Sodium sulfate + SS 0.5%	0	0	0	0	0	0	0	0
21. Sodium sulfate + SS 1%	0	0	0	0	0	0	0	0

[a] darkened lenticels only

Table 3. Measured pH values of various flotation solutions.

	pH at specific gravity			
pH	1.03	1.04	1.05	1.06
1. Water 7.0				
2. Water + Steri-Seal 0.5 % 10.7				
3. Water + Steri-Seal 1% 11.5				
4. Sodium carbonate	11.3	11.4	11.4	11.4
5. Sodium carb. + SS 0.5%	11.5	11.5	11.5	11.5
6. Sodium carb. + SS 1%	11.7	11.6	11.7	11.7
7. Potassium carb.	11.2	11.3	11.3	11.2
8. Potassium carb. + SS 0.5%	11.3	11.4	11.4	11.4
9. Potassium carb. + SS 1%	11.4	11.5	11.5	11.5
10. Lignosite	5.1	5.0	5.0	4.9
11. Lignosite + SS 0.5	6.1	5.6	5.4	5.2
12. Lignosite + SS 1%	7.4	6.5	5.9	5.6
13. Xeda F ("pH 10.6 formulation")	9.6	9.6	9.7	9.7
14. Xeda F + SS 0.5%	10.2	10.2	10.3	10.3
15. Xeda F + SS 1%	10.6	10.5	10.7	10.7
16. Calcium chloride	7.0	7.0	6.0	6.0
17. Calcium chloride + SS 0.5%	10.4	10.4	10.3	10.3
18. Calcium chloride + SS 1%	11.2	11.1	11.0	10.9
19. Sodium sulfate	7.0	7.2	7.4	7.6
20. Sodium sulfate + SS 0.5%	10.4	10.5	10.5	10.4
21. Sodium sulfate + SS 1%	11.1	11.1	11.2	11.1

Table 4. Injury (phytotoxicity) rating on Oregon Comice pears floated in combination solutions at specific gravity 1.05 in combination with 1% Steri-Seal. All fruit were thoroughly rinsed with fresh water following flotation for the indicated length of time. Temperature ranges indicate solution temperatures during flotation. All fruit were maintained at ~32 F before and after flotation. November-December 2001.

Abbreviations: L = lignosite; K = potassium carbonate; X = Xeda F
Injury rating: 0= none, 1= slight, 2 = moderate, 3= severe

	Flotation temperature and time (min.)											
	35-40 F				**50-55 F**				**63-68 F**			
% / %	15	30	45	60	15	30	45	60	15	30	45	60
1. 10 L 90 K	0	0	0	0	0	2	3	3	2	3	3	3
2. 25 L 75 K	0	0	0	0	0	2	3	3	3	3	3	3
3. 50 L 50 K	0	0	0	0	0	0	0	0	3	3	3	3
4. 10 L 90 X	0	0	2	2	0	0	3	3	3	3	3	3
5. 25 L 75 X	0	0	0	0	0	0	2	2	3	3	3	3
6. 50 L 50 X	0	0	0	0	0	0	0	0	3	3	3	3
7. 10 K 90 X	0	0	2	2	0	2	3	3	3	3	3	3
8. 25 K 75 X	0	0	2	2	0	2	3	3	3	3	3	3
9. 50 K 50 X	0	0	0	0	0	3	3	3	2	3	3	3
10. 10 X 90 K	0	0	0	0	0	2	3	3	1	2	3	3
11. 25 X 75 K	0	0	0	0	1	2	3	3	1	2	3	3

Table 5. Measured pH values of various solutions using combinations of flotation materials.

Flotation combination	pH
1. 10% lignosite + 90% K carbonate	10.9
2. 25% lignosite + 75% K carbonate	10.6
3. 50% lignosite + 50% K carbonate	9.9
4. 10% lignosite + 90% Xeda F	10.4
5. 25% lignosite + 75% Xeda F	9.9
6. 50% lignosite + 50% Xeda F	9.2
7. 10% K carbonate + 90% Xeda F	10.8
8. 25% K carbonate + 75% Xeda F	10.9
9. 50% K carbonate + 50% Xeda F	11.1
10. 10% Xeda F + 90% K carbonate	11.2
11. 25% Xeda F + 75% K carbonate	11.2

Table 6. Incidence of decay at wounds in Bosc pears floated in various solutions. Pears were artificially wounded, dipped 30 seconds in spore suspensions of either pathogen (1 x 10^4 spores per ml), rinsed, then floated for 2 minutes. Decay evaluated 7 weeks after inoculation.

	Percent of wounds infected	
	Botrytis cinerea	*Penicillium expansum*
1. Water	94.6 a	80.6 a
2. Water + Steri-Seal 0.5 %	53.0 c	60.0 b
3. Water + Steri-Seal 1%	21.6 d	52.0 bc
4. Sodium carbonate	80.0 ab	39.0 cd
5. Sodium carb. + SS 0.5%	82.0 ab	25.6 cd
6. Sodium carb. + SS 1%	40.6 cd	26.6 cd
7. Potassium carb.	75.6 b	29.0 cd
8. Potassium carb. + SS 0.5%	73.0 b	28.0 cd
9. Potassium carb. + SS 1%	29.6 d	19.0 d
10. Lignosite	94.6 a	85.6 a
11. Lignosite + SS 0.5	66.6 bc	62.6 b
12. Lignosite + SS 1%	40.0 cd	53.6 bc
13. Xeda F ("pH 10.6 formulation")	96.0 ab	62.0 b
14. Xeda F + SS 0.5%	22.0 d	25.6 bc
15. Xeda F + SS 1%	12.0 d	20.6 d
16. Calcium chloride	91.6 ab	60.6 c
17. Calcium chloride + SS 0.5%	36.0 c	55.0 bc
18. Calcium chloride + SS 1%	17.0 d	50.0 bc
19. Sodium sulfate	83.0 ab	69.6 ab
20. Sodium sulfate + SS 0.5%	23.0 d	47.0 bc
21. Sodium sulfate + SS 1%	18.0 d	33.6 cd

Conclusions: Pear packers have or will have in the future expanded options for pear flotation. With respect to phytotoxicity and decay control, there are new materials that appear to be suitable for use in the pear industry. Other experiments listed above will be evaluated early in 2001; results are expected for oral presentation at the Pear Research Review.

PROPOSAL FOR 2002

Objective: The goal of this research is to develop a storage decay control program for winter pears in which diverse, independent decay control practices contribute to dependable reduction of postharvest diseases.

Justification for Proposed Research: Postharvest decay continues to cause significant economic losses in the pear industry. This research program is specifically focused on the development and evaluation of control tactics for pear decay.

Procedures: This project will continue to focus both on the development of control techniques and on the feasibility of their integration into production schemes. The research will be conducted in the orchards and laboratories of the Southern Oregon Research and Extension Center in Medford, and in commercial orchards and packinghouses where appropriate. These areas will be emphasized:

1. Explore strategies to control postharvest decay by integration of cultural and nutritional practices.

2. Evaluate products, dosages, and timing of chemical applications to maximize benefit for control of both orchard and postharvest diseases. In the orchard, investigate fungicide spray programs directed at pear scab that may have beneficial effects in reducing postharvest decay.

3. Continue studies of biocontrol agents and how they may be used most effectively in different types of pear handling and storage systems.

4. Test novel storage atmospheres for winter pears that maximize storage life and/or are suppressive to decay.

Estimated Duration: 1 year.

Storage Decay Research
David Sugar
Budget Requested:

Item	Amount
Salaries and Wages	14,125
Services and Supplies	5,475
Travel	400
Total	20,000

CONTINUING PROJECT

Title: Control of decay of pear

Project Leader: Robert A. Spotts
Cooperators: Paul Chen
David Sugar
Victor Guerrero Prieto

Funding History:
Year initiated: 1979
Funding in 2001-2002: $30,000
Funding requested for 2002-2003: $38,044

Significant Findings:
Preharvest application of Flint failed to control blue mold in stored d'Anjou pear fruit, but CIM (*Cryptococcus* yeast) and Ziram application gave good control. Fludioxonil, JAN PL-40, and CIM controlled blue mold and gray mold in a postharvest drench application. The percent of *Penicillium expansum* spores resistant to fludioxonil was less when fludioxonil was mixed with CIM than when fludioxonil was used alone. An experimental product containing citric acid failed to control blue and gray mold. Vegetable oil (Fruit Shield) and zinc (Flowzin) did not control blue mold, but CIM alone or combined with the oil gave good control. Sanitation (cleaning and fumigation with quaternary ammonium compounds) reduced the level of *P. expansum* spores in the air and on surfaces in a commercial packinghouse. Spores of *Botrytis cinerea* in orchard air, litter, and on fruit surfaces at harvest, 2001 were at their lowest level in several years. Preliminary relationships between levels of airborne spores of *B. cinerea* and *P. expansum* and stem end decay were determined. Survival structures (sclerotia) of *B. cinerea* were found on about 20% of infected fruit on the orchard floor, and over 90% were still viable in July, 2001. Wild blackberries were not a source of gray mold spores during pear harvest in 2000 and 2001. Germination times for spores of *B. cinerea*, *Mucor piriformis*, and *P. expansum* on pear tissue at 30° F were, 37, 97, and over 100 hours, respectively. Blue mold, gray mold, and Mucor rot of d'Anjou pears were lowest in fruit harvested one week before commercial harvest and highest 3 weeks after commercial harvest.

Objectives:
1. Biological and chemical control of decay of pear.
2. Studies on decay pathogens.

Procedures:
Biological and chemical control of decay of pear
A. Evaluation of JAN PL-40 and fludioxonil (Scholar) for control of blue mold and gray mold and compatibility of Scholar with CIM.

d'Anjou pear fruit was harvested at commercial maturity and not wounded. Fruit were treated in a recirculating drencher with the following treatments (all rates per 100 gal):

1. Scholar at 16 oz
2. Scholar at 12 oz
3. Scholar at 8 oz
4. Scholar at 4 oz
5. Scholar at 2 oz
6. CIM at 1.3 x 10^8 cfu/ml

7. CIM at 1.3 x 10^8 cfu/ml + Scholar at 2 oz
8. JAN PL-40 at 500 ppm a.i.
9. JAN PL-40 at 1000 ppm a.i.
10. Water control

Drench solutions contained conidia of *Penicillium expansum* or *Botrytis cinerea*. Fruit were drenched, drained, then transferred to polyethylene-lined wooden boxes. Three replicate boxes per treatment (about 19 kg fruit per box) were stored at 30° F. Fruit were evaluated after 2 and 3 months of storage for *B. cinerea* and *P. expansum*, respectively. In addition, treatments 3, 4, and 10 were repeated using dirty dump tank water from the MCAREC packingline.

B. Preharvest fungicides and CIM for decay control.
Vangard was applied to trees starting in April. Three replicate trees of d'Anjou were sprayed to runoff with a handgun sprayer at 300 psi. Trees were sprayed at pink, petal fall, and first cover. Flint was applied at 28 and 14 days before harvest. Unsprayed trees were treated with Ziram or CIM at 14 days before harvest. Control trees received no fungicide or yeast. At harvest, four boxes of fruit per tree were drenched *P. expansum*, then stored in polyethylene-lined wooden boxes at 30° F. Decay was evaluated after 3, 6, and 8 months.

C. Does CIM prevent or slow resistance to fludioxonil?
A study was done to measure quantitative shifts in resistance of *P. expansum* to fludioxonil in fludioxonil suspensions with and without CIM. Spores of a fludioxonil-resistant strain and a fludioxonil-sensitive strain of *P. expansum* were mixed to produce suspensions containing 2.4% and 3.5% fludioxonil-resistant spores. d'Anjou pear fruit were wounded, then inoculated with the spore suspensions with and without 1 x 10^8 colony forming units per ml of CIM from a WDG formulation. Fruit were incubated for 1 to 2 weeks. When decay lesions sporulated, spores were removed with a loop and placed in sterile distilled water + Tween 80 solution. Spores were used to inoculate a second lot of fruit. The spores also were plated on potato dextrose agar with and without 10 ppm a.i. fludioxonil to determine if the percent fludioxonil –resistant spores in the suspension changed from the initial percent. Similarly, when spores developed on the lesions in the second lot of fruit, they were removed and plated to determine percent fludioxonil resistance.
D. Evaluation of citric acid for decay control.
Wounded d'Anjou pears were dipped in a suspension containing citric acid in sodium acid pyrophosphate (1:1) + sodium dodecyl benzene sulfonate. After treatment, wounds were inoculated with a spore suspension of *B. cinerea* or *P. expansum*. Decay was evaluated after 7 days.

E. Evaluation of Fruit Shield and Flowzin for control of blue mold
Wounded d'Anjou pears were dipped in a suspension containing Fruit Shield (vegetable oil) at 4% and 8% (v/v) with and without CIM at 2 x 10^8 cfu/ml, CIM alone, Flowzin (zinc oxide) at 19 ml with and without CIM, and Fruit Shield (8%) + CIM + Flowzin (19 ml). Treatment suspension also contained *P. expansum.* After treatment, fruit were stored at 30° F and decay evaluated after 3 months.

F. Sanitation and quaternary ammonia fumigation for reduction of surface spore load.
Surfaces in a commercial packinghouse were sampled before and after cleaning and before and after fumigation with quaternary ammonia. Surface samples were collected at 17 locations in the pear packingline area and in two cold rooms. Surface samples were taken with cotton swabs dipped in sterile distilled water. Spores were removed from the swabs in the laboratory by sonication and rotary shaking. Spore suspensions were plated on petrie dishes, incubated 4 days, and colonies counted. Air samples were collected with a portable sampler that impinges 20 liters of air onto a petrie plate containing APDA. Plates were incubated and counted as described above.

2. Studies on decay pathogens

A. Air, soil, litter, and fruit surface Penicillium and Botrytis spore levels and fruit decay.

This epidemiological study was initiated to begin collecting data on the concentrations of spores of *P. expansum and B. cinerea* in orchard air, soil, litter, and on fruit surfaces preceding and during harvest. This study will help determine the concentrations in a pear orchard with a history of decay and will relate the concentrations to the amount of decay developing in stored fruit.

In an orchard with a history of gray mold, air and litter samples were taken monthly from April through harvest in September. At harvest, spores were washed from fruit surfaces and counted, stems were plated to determine presence of decay fungi, and 20 boxes of fruit (2 boxes per tree from 10 replicate trees) were stored at 30° F and evaluated for decay after 3, 6, and 8 months.

B. Airborne spore inoculum dose:disease incidence for stem end blue and gray mold of pear.

Pear fruit were inoculated in an aluminum tower of 2.06 m height. Fruit were placed in the bottom of the tower in two cardboard trays, 22 fruit per tray with the stems up. Conidia/talc mixtures were used to obtain a range of inoculum sizes from 0.01 to 0.5 mg of conidia. Each mixture was weighed, transferred into a sterile glass tube, and forcefully blown into the top center of the tower. Spores were allowed to settle for 20 minutes, then fruit were removed and placed in a cardboard fruit box lined with a perforated polyethylene bag. After 3, 6, and 8 months of storage at 30° F, stem end infection was determined visually. Density of conidia of *B. cinerea* and *P. expansum* settling onto the surface and in the tower air was determined.

C. Survival of decay spores in litter in orchard plots.

Litter from the top 2 cm of a pear orchard was removed and thoroughly mixed. Spores of *P. expansum* and *B. cinerea* from cultures were added to the litter and thoroughly mixed. The litter was placed in wire mesh baskets. Baskets were placed in holes in the orchard so the top of the litter in the basket was at the same level as the orchard litter surface. Litter was sampled once each month to determine the populations of *B. cinerea* and *P. expansum* in the litter.

D. Importance of sclerotia in the epidemiology of Botrytis.

Sclerotia are hard resting bodies of *Botrytis* that are resistant to unfavorable conditions, may remain dormant for long periods of time, then germinate upon the return of favorable conditions. Their importance in the epidemiology of gray mold of pear has never been studied. About 20 isolates of B. cinerea were inoculated into d'Anjou pear fruit in various pair combinations. After sclerotia formed, the fruit were placed in the orchard to overwinter. In the spring, the sclerotia werecollected and germinated to determine survival. In addition, naturally infected fruit on the ground in the orchard were marked and monitored for sclerotia. In spring, these sclerotia were collected and germinated. Information on survival, germination, and spore production of sclerotia will help us relate the importance of these structures to the level of gray mold.

E. Role of blackberries in the epidemiology of Botrytis.

B. cinerea infects many hosts, including both pear fruit and blackberry fruit. Blackberries are common weeds near many orchards, especially in Hood River and White Salmon. This study determined if gray mold spores from blackberry can infect pear fruit. In addition, the time of spore production on blackberry in relation to pear harvest was determined.

F. Germination of decay pathogens at selected temperatures.

This study is a continuation of research initiated three years ago. Spore germination was studied first in pear juice and on potato dextrose agar plates because measurements were much faster than on pear tissue. Once approximate germination times at each temperature were determined, studies shifted to germination on the pear tissue. "Plugs" were cut from the fruit and sliced into 0.5 mm thick "wafers".

"Wafers were placed directly on glass microscope slides and kept in a sterile petri dish on wet, sterile filter paper. Inoculum of *B. cinerea, M. piriformis,* and *P. expansum* was prepared and used to inoculate each "wafer". After the desired incubation times at each temperature, plates were removed and spore germination determined microscopically.

G. Harvest maturity in relation to decay susceptibility.

From limited data, it appears that overmature pear fruit are more susceptible to decay than less mature fruit. In this study, we quantified this relationship. Eighteen boxes of d'Anjou pears were harvested at pressures from 16 to 12.6 pounds. Immediately after harvest, six boxes fruit were drench-inoculated with *B. cinerea*, *M. piriformis*, or *P. expansum.* Fruit were stored at 30°F in poly-lined wooden boxes, and decay evaluated after 1, 2, and 3 months for mucor rot, gray mold, and blue mold, respectively. In addition, fruit at harvest was analyzed for soluble solids, starch index, and polygalacturonase inhibitor protein (PGIP), thought to be related to decay resistance

Results and discussion:

1. Biological and chemical control of decay of pear

A. Evaluation of JAN PL-40 and fludioxonil (Scholar) for control of blue mold and gray mold and compatibility of Scholar with CIM.

Incidence of blue mold caused by *P. expansum* ranged from 0 to 13.1% (Table 1). All treatments gave significant decay control compared with the water control. None of the treatments were different from each other. Incidence of gray mold caused by *B. cinerea* ranged from 0 to 28.2% (Table 1). All treatments gave significant decay control compared with the water control. Only one treatment, CIM alone, was significantly different from all of the other treatments, and this resulted from an unusual incidence of decay in one of the three replicate boxes.

In a drench of fruit with contaminated packinghouse water, Mucor rot constituted a large amount of decay in the Scholar treatments. When Mucor infected fruit were removed from the analysis, resulting decay levels were 7.2, 1.7, and 2.5% for the water control, Scholar at 4 oz, and Scholar at 8 oz, respectively. Because of high variability, there were no significant differences among treatments in this analysis.

None of the treatments caused any phytotoxicity to the d'Anjou pear fruit in these trials.

B. Preharvest fungicides and CIM for decay control.

One preharvest application of CIM or Ziram reduced blue mold and total decay (Table 2.). Vangard applied in spring followed by two preharvest Flint applications did not control blue mold when compared to decay of fruit from unsprayed trees.

C. Does CIM prevent or slow resistance to TBZ?

Previously, we reported that the shift in resistance of P. expansum to TBZ was slowed by CIM when initial resistance is low. Additional experiments with TBZ were unsuccessful for a variety of technical reasons. Recent experiments were done with CIM and fludioxonil. Rapid increase to a high level of resistance occurred with a low rate of fludioxonil, but this increase in resistance was slowed by mixing CIM with fludioxonil (Table 3).

D. Evaluation of citric acid for decay control.

Citric acid did not control blue mold or gray mold of fruit inoculated (Table 4). The treatment foamed considerably, perhaps due to the soap in the citric acid formulation. No phytotoxicity was observed.

E. Evaluation of Fruit Shield and Flowzin for control of blue mold

Fruit Shield (vegetable oil) and Flowzin (zinc) did not control decay. The Fruit Shield was compatible

with CIM, but the Flowzin was not. CIM alone and combined with the low rate of vegetable oil gave 89% and 97% control, respectively (Table 5).

F. Sanitation and quaternary ammonia fumigation for reduction of surface spore load.
Concentrations of *P. expansum* spores on equipment surfaces and in air in a commercial packinghouse were greatly reduced by cleaning, and a further slight reduction occurred following fumigation with a quaternary ammonium compound (Table 6). The spore concentration gradually increased as the packing season progressed.

2. Studies on decay pathogens

A. Air, soil, litter, and fruit surface Penicillium and Botrytis spore levels and fruit decay.
Concentrations of spores of *B. cinerea* in orchard air, litter, and on the surface of fruit were the lowest in several years in fall, 2001(Table 7). No *B.cinerea* was found in the stems of fruit and no gray mold developed when orchard-run fruit were wounded. Evaluation of decay of fruit placed in cold storage will not be completed until spring, 2002.

B. Airborne spore inoculum dose:disease incidence for stem end blue and gray mold of pear.
Blue mold and gray mold stem end decay in this study ranged from 0 to almost 60%. Decay incidence was related to spore dose (Figure 1). A second year of inoculations is necessary to confirm these relationships. These curves will be used to determine the potential decay in lots of fruit from various orchards where inoculum dose has been measured.

C. Survival of decay spores in litter in orchard plots.
B. cinerea spores died quickly in litter in the orchard, and levels remained low from May through September (Table 8). *P. expansum* spores survived the entire summer, and populations dropped only after harvest in late September.

D. Importance of sclerotia in the epidemiology of Botrytis.
Over 20 isolates of B. cinerea inoculated into Anjou and Bartlett fruit produced from 0 up to 346 sclerotia per fruit. Viability of these sclerotia decreased gradually through the summer from over 50% in March to about 20% in July. Viablility of natural sclerotia from orchard litter was over 90% in July. Germination of sclerotia in the orchard was rare.

E. Role of blackberries in the epidemiology of Botrytis.
B. cinerea from infected blackberry fruit were pathogenic when inoculated into Anjou pear fruit. No *Botrytis* sporulation was observed on blackberries next to pear orchards prior to pear harvest in 2000 or 2001.

F. Germination of decay pathogens at selected temperatures.
Germination of spores of decay pathogens was generally from 1 to several hours slower on disks cut from pear fruit flesh than in pear juice (Table 9). At 30° F, germination times of B. cinerea, M. piriformis, and P. expansum were 37, 97, and over 163 (estimate) hours, respectively.

G. Harvest maturity in relation to decay susceptibility.
Blue mold, gray mold, and Mucor rot all were lowest in fruit harvested August 29,one week before commercial harvest, and highest in the last harvest on September 26 (Table 10). Much variability occurred between these times. Decay susceptibility did not appear to be related to any of the maturity indices or to PGIP levels.

Table 1. Effect of postharvest fungicide drench on control of blue and gray mold of Anjou pear

		Percent decay incidence[y]	
Treatment	Rate	Blue mold	Gray mold
Scholar 50WP	2 oz product/100 gal	1.6a	0.0a
Scholar 50WP	4 oz	0.0a	1.5a
Scholar 50WP	8 oz	0.6a	0.9a
Scholar 50WP	12 oz	0.5a	0.4a
Scholar 50WP	16 oz	0.5a	0.5a
CIM[z]	1.3 x 10^8 cfu/ml	0.5a	7.0b
CIM[z] + Scholar 50WP	1.3 x 10^8 cfu/ml + 2 oz	1.1a	1.6a
JAN PL-40	500 ppm a.i.	0.5a	1.0a
JAN PL-40	1000 ppm a.i.	0.0a	0.0a
Water control	---	13.1b	28.2c

[y]Numbers followed by the same letter within columns are not significantly different at P = 0.05 according to least significant difference test.
[z]*Cryptococcus infirmo-miniatus* WDG formulation.

Table 2. Decay control with preharvest fungicides, 2000-2001

Fungicide and rate[1]	Blue mold (%)	Total decay (%)
CIM 3.5x10^7 cfu/ml	6.2a	9.8a
Ziram 8.0 lb/acre	11.2a	12.3a
Flint3.0 oz/acre	24.5b	25.5b
Unsprayed	19.5b	23.0b

[1]CIM and Ziram applied 14 days preharvest, Flint at 28 and 14 days preharvest.

Table 3. Effect of CIM on resistance of *P. expansum* to fludioxonil, 2001

	Percent of *P. expansum* spores resistant to fludioxonil	
Treatment	Trial 1	Trial 2
Sterile distilled water	0.0	0.4
CIM	0.0	0.7
Fludioxonil 0.5 oz/100gal + CIM	0.3	0.0
Fludioxonil 0.5 oz/100 gal	100.0	42.7
Initial % resistance	2.4	3.5

Table 4. Effect of citric acid on decay of wound-inoculated Anjou pears

	Percent decay		Lesion diameter (mm)	
Treatment	Gray mold	Blue mold	Gray mold	Blue mold
Citric acid	15.2a	100.0a	26.2a	30.6a
Water control	7.6a	97.0a	20.9a	28.8a

Table 5. Effect of vegetable oil, zinc, and CIM on blue mold of Anjou pears

Treatment	Percent blue mold
CIM	9.1a
CIM + 4% oil	2.3a
CIM + 8% oil	5.7a
CIM + 8% oil + zinc	85.2b
4% oil	89.8bc
8% oil	87.5b
Zinc	100.0c
Zinc + CIM	89.8bc
Water control	83.0b

Table 6. Effect of packinghouse sanitation on *Penicillium expansum* spore levels

Date		n^2	
July 19, 2000	Before cleaning	1756	--
August 10, 2000	After cleaning	38	0.7
August 14, 2000	After fumigation	29	0.2
October 19, 2000	---	96	0.4
January 17, 2001	---	237	12.1
April 10, 2001	---	2546	36.6

Table 7. Air, surface, and litter populations of *Botrytis cinerea* in a pear orchard at harvest and gray mold of Anjou pears after 8 months cold storage

	Year		
Colony forming units	1999	2000	2001
Per gram dry litter	229	22	0.4
Per M^3 of orchard air	173	490	10
On fruit surface (per fruit)	1,987	140	0
Gray mold in storage (%)	6.6	3.9	decay not yet evaluated

Table 8. Survival of spores of *B. cinerea* and *P. expansum* in orchard litter

	Colony forming units per gram dry litter	
Date	*B. cinerea*	*P. expansum*
April 17	16,766	22,102
May 15	83	12,931
June 20	50	18,728
July 18	37	16,522
August 22	19	22,402
September 20	21	5,850

Table 9. Hours required for germination of spores of decay pathogens in pear juice and on Anjou pear tissue disks

	B. cinerea		M. piriformis		P. expansum	
Temperature (F)	Juice	Tissue	Juice	Tissue	Juice	Tissue
30	37	37	92	97	163	ND
41	11	12	27	30	31	38
50	7	9	12	13	19	27
68	4	7	4	7	10	13

Table10. Harvest maturity of Anjou pear and relation to decay susceptibility

	Maturity index				Percent fruit infected		
Harvest date	Firmness (lbs) UC	Firmness (lbs) Instron	Starch index (0-5)	Soluble solids (Brix)	*Botrytis cinerea*	*Mucor piriformis*	*Penicillium expansum*
Aug 29	15.9	14.7	1.3	11.8	5.0	11.3	6.2
Sept 1	16.0	14.5	1.2	11.8	7.3	18.5	10.4
Sept 5	15.1	13.9	1.5	12.2	14.0	26.0	16.3
Sept 12	13.9	13.2	2.9	12.2	2.0	4.9	5.5
Sept 19	13.0	12.5	3.6	12.9	7.8	18.3	18.0
Sept 26	12.6	12.3	4.3	13.6	13.7	27.6	24.0

PROPOSAL FOR 2002

Objectives:

1. Chemical, heat, and biological control of decay of pear.
2. Studies on decay pathogens.

Procedures:

Chemical, heat, and biological control of decay of pear

A. MCP and ethylene treatment and effect on decay.

Fruit will be inoculated with spores of blue mold and gray mold fungi before and after preconditioning fruit with 100 ppm ethylene for 1, 2, and 3 days, followed by MCP at 50 ppb for 24 hours. Control fruit will be inoculated and treated with ethylene but not MCP. Fruit will be stored in air at 30° F and decay evaluated after 2 and 3 months for gray mold and blue mold, respectively.

B. Copper/silver ion generator evaluation.

Copper and silver ions are well-known biocides and have been used in a variety of applications, including Apollo space flights and commercial swimming pools.

A generation system capable of producing copper and silver ions will be installed in the dump tank of the commercial packingline at MCAREC. About 14 bins of fruit will be processed without operating the generator, then the same quantity of fruit from the same lot will be processed with the generator turned on. Throughout each run, 6 boxes of punctured cull fruit will be collected, stored at 30° F, and decay evaluated monthly. During each run, dump water samples will be removed hourly, and the concentration of decay spores determined. Dump water temperature, pH, specific gravity, and concentrations of copper will be monitored throughout the study.

C. Evaluation of a hot water pressure washer system for decay control.

This research is part of a larger cooperative study with USDA personnel and is partly funded by an APHIS grant. The pathology component is as follows:

Evaluation of populations of decay spores in water. Effect of the hot water pressure washer system (HWS) on populations of decay spores in the water system of the MCAREC

packingline will be determined by dilution plating onto acidified potato dextrose agar. Replicate samples will be taken before heating begins, then hourly throughout the day.

Evaluation of the effect of the HWS on fruit decay. d'Anjou pear fruit will be puncture-inoculated with spores of the main decay pathogens, *Botrytis cinerea*, *Mucor piriformis*, *Penicillium expansum*, and a sterile distilled water control. Fruit will be run through the packingline with and with the HWS in operation. HWS operating conditions will be those determined in preliminary tests to give the maximum temperature and time of fruit exposure without injury to the fruit. Treated fruit will be stored at -1° C and decay evaluated after 1, 2, and 3 months for *M. piriformis*, *B. cinerea*, and *P. expansum*, respectively. Fruit also will be evaluated for heat injury. The experiment will be repeated three times, using a total of 72 boxes of fruit.

D. *Evaluation of fludioxonil (Scholar) for control of blue mold and gray mold and compatibility with ethoxyquin and Mertect.*

d'Anjou pear fruit will be harvested at commercial maturity and surface-sterilized but not wounded. Fruit will be treated in a recirculating drencher with the following treatments (all rates per 100 gal):

1. Scholar at 16 oz + ethoxyquin
2. Scholar at 4 oz + ethoxyquin
3. Scholar at 4 oz + Mertect at 16 oz
4. Scholar at 4 oz
5. CIM
6. Water control

Drench solutions will also contain conidia of *Penicillium expansum* or *Botrytis cinerea*. Fruit will be drenched, stored at 30° F in air, and evaluated after 2 and 3 months of storage for *B. cinerea* and *P. expansum*, respectively.

E. *Preharvest fungicides for decay control.*
Flint, Ziram, and Ferbam will be applied at 14 days before harvest. Control trees will receive no fungicide. At harvest, fruit will be drenched with spores of *P. expansum*, then stored at 30° F. Decay will be evaluated after 3, 6, and 8 months.

F. Does CIM prevent or slow resistance to fludioxonil?
CIM is compatible and synergistic with fludioxonil, particularly low rates of fludioxonil. However, use of low rates of fungicides is a concern because of development of resistance. A study will be done to measure quantitative shifts in resistance of *P. expansum* to fludioxonil in fludioxonil suspensions with and without CIM. Spores of a fludioxonil-resistant strain and a fludioxonil-sensitive strain of *P. expansum* will be mixed to produce suspensions containing about 1% fludioxonil-resistant spores. d'Anjou pear fruit will be wounded, then inoculated with the spore suspensions with and without CIM from a WDG formulation. The suspensions also will contain 0, 0.5, 1.0, and 2.0 oz fludioxonil per 100 gallons. When sporulation is present on decay lesions, spores will be removed and used to inoculate a second lot of fruit. The spores also will be plated on potato dextrose agar with and without fludioxonil to determine if the percent fludioxonil–resistant spores in the suspension has changed from the initial percent. Similarly, when spores develop on the lesions in the second lot of fruit, they will be removed and plated to determine percent fludioxonil resistance.

2. Studies on decay pathogens

A. Air, litter, and fruit surface Penicillium and Botrytis spore levels and fruit decay.

This epidemiological study was initiated to collect data on the concentrations of spores of *P. expansum and B. cinerea* in orchard air, soil, litter, and on fruit surfaces preceding and during harvest. This study will help determine the concentrations in a pear orchard with a history of decay and will relate the concentrations to the amount of decay developing in stored fruit.

In an orchard with a history of gray mold, air and litter samples will be taken monthly from June through harvest in September. At harvest, spores will be washed from fruit surfaces and counted, stems will be plated to determine presence of decay fungi, and 20 boxes of fruit (2 boxes per tree from 10 replicate trees) will be stored at 30° F and evaluated for decay after 3, 6, and 8 months.

B. Airborne spore inoculum dose:disease incidence for stem end blue and gray mold of pear.

This will be the second year of this study. Pear fruit will be inoculated in an aluminum tower. Fruit will be placed in the bottom of the tower with the stems up. Conidia/talc mixtures will be used to obtain a range of inoculum sizes from 0.01 to 0.5 mg of conidia. Each mixture will be forcefully blown into the top center of the tower. Spores will be allowed to settle for 20 minutes, then fruit will be removed. After 3, 6, and 8 months of storage at 30° F, stem end infection will be determined. Density of conidia of *B. cinerea* settling onto the surface will be determined by placing glass microscope slides coated with a thin layer of silicone grease at different locations on the trays. Conidia on slides will be counted under a microscope. Density of spores of *P. expansum* on the surface will be determined by placing three petri dishes containing APDA on the trays. Density of conidia of *B. cinerea* and *P. expansum* in the air inside the tower will be determined by sampling with a portable air sampler for agar plates through a port on the side of the tower.

C. Survival of Botrytis in weeds in orchard plots.

This study will examine the importance of common orchard weeds as a source of spores of *Botrytis cinerea*. The following weeds and additional organic matter sources will be collected from a pear orchard in spring:

White sweetclover	Annual bluegrass
Common chickweed	Common mallow
Quackgrass	Dandelion
Dead pear leaves	Pear blossom petals

Leaves, stems, and flower parts of each species (when present) will be sterilized and cut into pieces. Weed pieces will be inoculated with spores of B. cinerea and incubated in petri dish moist chambers for 3 days.

"Starched" cheesecloth pieces were used to make envelopes, then filled with pieces of colonized weeds and placed on the ground in the orchard. Colonization and survival will be determined monthly by plating weed pieces on agar.

D. Importance of sclerotia in the epidemiology of Botrytis.

Sclerotia are hard resting bodies of the fungus that are resistant to unfavorable conditions, may remain dormant for long periods of time, then germinate upon the return of favorable conditions. Their importance in the epidemiology of gray mold of pear has never been studied. About 20 isolates of B. cinerea will be inoculated into d'Anjou pear fruit in various pair combinations. After sclerotia form, the fruit will be placed in the orchard to overwinter. In the spring, the sclerotia will be collected and germinated to determine survival. Information on survival,

germination, and spore production of sclerotia will help us understand the importance of these structures as related to the level of gray mold. This is the second year of this study.

E. Role of blackberries in the epidemiology of Botrytis.

B. cinerea infects many hosts, including pear fruit and blackberry fruit. Blackberries are common weeds near many orchards, especially in the Mid-Columbia district of Oregon and Washington. This study will determine if gray mold spores from blackberry can infect pear fruit. In addition, the time of spore production on blackberry in relation to pear harvest will be determined, and spore gradients from blackberry thickets into pear orchards will be monitored

F. Germination of decay pathogens at selected temperatures.

Approximate germination times at each temperature have been determined in pear juice and the number of time/temperature combinations have been narrowed down. Studies will shift to germination on the pear tissue. Information on how much time is required for germination at temperatures from 30° to 68° F, combined with information on the moisture and temperature status of fruit surfaces in cold storage, will help determine where infection is occurring. "Plugs" will be cut from the fruit and sliced into thin "wafers". "Wafers will be placed directly on glass microscope slides which will be kept in a sterile petri dish on wet, sterile filter paper. Inoculum of *Botrytis cinerea* will be used to inoculate each "wafer". After the desired incubation times, spore germination will be determined microscopically. The study will be repeated with *P. expansum, M. piriformis*, and *Pezicula malicorticis.*

G. Harvest maturity in relation to decay susceptibility.

From limited data, it appears that overmature pear fruit are more susceptible to decay than less mature fruit. In this study, we will try to quantify this relationship. Eighteen boxes of d'Anjou pears will be harvested weekly beginning one week before commercial harvest. Immediately after harvest, six boxes of orchard-run fruit will be drench-inoculated with spores of *B. cinerea*, *M. piriformis*, or *P. expansum*. Fruit will be stored at 30°F and decay evaluated after 1, 2, and 3 months for mucor rot, gray mold, and blue mold, respectively. In addition, fruit at harvest will be analyzed for soluble solids, firmness, and polygalacturonase inhibitor protein (PGIP), thought to be related to decay resistance. The relationships between pressure, PGIP, and decay will be determined.

Estimated duration:

The biological control research will proceed until the OSU yeast, CIM, is available to the fruit industry as a registered product. The registration package for CIM has been submitted to EPA. Chemical control trials usually require about two years. Epidemiological studies with spore populations, sclerotia, and inoculum dose/decay incidence relationships from tower data will take a minimum of two years to complete. Harvest maturity studies require two to three years before recommendations can be made confidently to the industry. MCP research will be completed in one year.

Budget requested:

Item	Amount
Salaries and wages	$36,574
Service and supplies	998
Travel	472
TOTAL	$38,044

CONTINUING REPORT
WPPC - Mattheis **Organization Project #17306**

Project Title: Management of Pear Fruit Ripening with 1-Methylcyclopropene (MCP)

PI: James Mattheis, Plant Physiologist
Organization: USDA, ARS, Wenatchee, WA

Co-PI: Paul Chen, Professor
Oregon State University, Mid-Columbia Experiment Station,
Hood River, OR

Rodney Roberts, Plant Pathologist
USDA, ARS, Wenatchee, WA

David Rudell**,** Biological Science Technician
USDA, ARS, Wenatchee, WA

Objectives:
A primary objective of postharvest management of pears is to prolong storage life by reducing the rate of fruit ripening. The combination of optimum maturity, refrigeration, postharvest chemical treatments and controlled atmosphere storage slow ripening and reduce physiological disorders and decay. Controlled atmosphere storage in particular reduces ethylene production as well as the capacity of fruit to respond to ethylene, responses that provide the residual effects of CA after fruit is removed from storage. Because of the importance of ethylene in regulating the processes of fruit ripening, practices that interfere with its production and/or action are useful in the commercial storage of pears.

Researchers at North Carolina State University, Dr. Ed Sisler and Dr. Sylvia Blankenship have identified a compound that interferes with fruit ethylene metabolism. This compound, 1-methylcyclopropene (MCP), inhibits ethylene perception and shows great potential as a tool for postharvest management of pears. MCP is a volatile compound that can be applied as a gas treatment without drenching fruit. Results with a number of fruit crops (Abdi *et al*., 1998; Fan *et al.*, 1999a,b; Fan *et al*. 2000; Fan *et al.*, 2001; Golding *et al.*, 1998) have demonstrated MCP treatment can reduce the rate of climacteric fruit ripening as well as development of a number of physiological disorders.

Objectives for 2002-2003:
1. Determine treatment conditions to maximize responses of pear cultivars to MCP.

2. Determine duration of responses when treated fruit are stored in RA or CA conditions.
3. Determine the impact of MCP treatments on fruit physiological disorders and decay.

Significant findings:
MCP treatment of 'Bartlett', 'Bosc', 'Comice' or 'd'Anjou' pears with MCP at concentrations between 0.1 to 1 ppm delays ripening and development of physiological and pathological disorders. 'Bosc' responses to MCP treatment are similar to those of 'd'Anjou', 'Comice' responses are intermediate between 'Bartlett' and 'd'Anjou'.

Treatment of commercially packed boxes of 'Bartlett' or 'd'Anjou' results in typical MCP responses (reduced respiration, ethylene production, slowed loss of quality, delayed onset of decay and development of physiological disorders).

The window for delaying MCP treatment of 'Bartlett' is 2 weeks after harvest to achieve maximum response. For 'd'Anjou', treatment can be delayed up to 4 weeks depending on the MCP treatment concentration.

Fruit temperature (32 to 68 ºF) during MCP treatment is not a critical determinant of fruit response.

The long-term effects of MCP for slowing ripening of 'Bartlett' pear are inconsistent between production seasons.

Partially ripe 'Bartlett' or 'd'Anjou' fruit treated with MCP ripen at a reduced rate compared to non-treated controls. The magnitude of MCP responses is dependent on fruit maturity when MCP is applied. This trend is evident when fruit are riper due to delayed harvest or delayed MCP treatment after harvest.

Ethylene treatments up to 10,000 ppm do not result in full recovery of the capacity to ripen in 'Bartlett' fruit treated with 0.1 or 0.5 ppm MCP.

The duration of MCP responses for 'Bartlett' fruit is dependent on storage temperature after treatment. Fruit stored at 68 ºF ripen within one month of treatment.

Storing 'Bartlett' or 'd'Anjou' fruit in CA following treatment with MCP prolongs the inhibition of ripening compared to RA storage. MCP concentration for □Bartlett□ can be lower for fruit stored in CA compared to RA.

MCP treatment does not increase sensitivity of 'Bartlett' or 'd'Anjou' fruit to CO_2 during CA storage.

Methods:
Pears were obtained from commercial orchards. Fruit were held at in air at 68 or 33 ºF or CA (1.5% O_2, 0.5% CO_2) until MCP treatments were conducted. The treatments were applied to fruit in sealed steel or plastic chambers at 70 ºF for 12 h.

MCP was generated from Ethylbloc powder provided by Agrofresh, Inc, a subsidiary of the Rohm and Haas Company. Target MCP concentrations, monitored by gas chromatography (Fan *et al*., 2000) were reached within 10-15 minutes after initiation of gas generation.

Fruit firmness was measured using a Mohr Digi-Test instrument (Mohr and Associates, Richland, WA). Titratable acidity (TA) was determined by titrating fresh juice to pH 8.2, and soluble solids content (SSC) was measured with a refractometer (Atago, Tokyo).
Fruit respiration and ethylene production were determined using gas chromatography (Fan *et al.*, 1999).

Fruit visual assessments. Peel color was rated 1:green to 5:yellow. Superficial and senescent scald were rated as 1:none, 2: 1 to 33%, 3: 34 to 66%, 4: 67 to 100% fruit surface with light brown discoloration, 5: 1 to 33%, 6: 34 to 66%, 7: 67 to 100% fruit surface with dark brown discoloration. Internal breakdown and core browning (browning within the core line) were rated as 1: none, 2: slight, 3: moderate, 4: severe.
Scuffing was rated as 1: absent, 2: present. Objective measures of fruit color were performed using a colorimeter.

Results and discussion:

Bartlett 2001-02

B1. 'Bartlett' pears treated the day of harvest with 0.1 or 0.5 ppm MCP for 12 h at 68 ºF were stored in air at 32 ºF. After 1, 2 or 3 months, fruit were exposed to ethylene gas at concentrations up to 10,000 ppm for 4 d at 68 ºF, then held at 68 ºF for 5 more days. Through the 3 month evaluation, none of the ethylene treatments resulted in full reversal of MCP effects. Ethylene treatments will also be conducted after 4 and 5 months storage.

B2. 'Bartlett' pears were harvested 4 times over a 14 d period with the initial harvest at commercial maturity. Fruit from each harvest were treated with 0.1 or 0.5 ppm MCP at 68 ºF for 12 h, then stored at 32 ºF in air or CA (1.5% O_2, 0.5% CO_2). After 2 months storage plus 7 days at 68 ºF, the incidence of core and internal browning increased with harvest date for control (non-MCP) fruit stored in air. CA storage or MCP treatment prevented development of core and internal browning. Control fruit stored in CA ripened normally during the 7 d at 68 ºF, however, MCP treated fruit did not degreen or soften appreciably regardless of harvest date, MCP concentration or storage environment. Similar evaluations will be performed after 4 and 6 months storage.

B3. Responses of 'Bartlett' pears to storage temperature were evaluated using fruit treated at harvest with 0, 0.1 or 0.5 ppm MCP. Pears were then stored in air at 31, 33 or 35 ºF. Both MCP concentrations prevented development of core and senescent browning at all temperatures through 3 months plus 7 days at 68 ºF. MCP treatments also prevented softening and yellowing after 1 month regardless of storage temperature. After 3 months, some softening and yellowing occurred in MCP treated fruit, however, fruit was not completely ripe in 7 days.

Fruit treated with MCP at harvest was also stored at 50 or 68 ºF. MCP treatment did not prevent ripening when fruit were stored at 68 ºF for 1 month after treatment. However, MCP-treated fruit stored at 50 ºF did not develop physiological disorders and ripened normally 1 month after treatment. After 2 months at 50 ºF, all MCP-treated fruit were senescent and had developed internal breakdown.

B4. To evaluate responses of MCP treated 'Bartlett' pears to CO_2 during CA storage, pears were treated with 0.1 or 0.5 ppm MCP then stored at 32 ºF in air or CA with 1.5 % O_2 plus 0.5, 1.5 or 2.5% CO_2. Typical MCP responses (lack of ripening, no development of physiological disorders) were detected through 90 days storage plus 7 days at 68 ºF. The exception was pears stored in CA with 2.5% CO_2, where lenticel breakdown was present after 90 days in check and MCP treated fruit.

D'Anjou 2000-01

A1. MCP treatment temperature. 'd'Anjou' pears were treated with 1 ppm MCP for 12 h at 32, 41, 50 or 68 ºF at harvest. Fruit were then stored at 32 ºF in air or CA (1.5% O_2 , 0.5% CO_2) for up to 9 months. MCP responses were similar regardless of temperature during treatment. Physiological disorders did not develop during ripening of air-stored MCP treated fruit. However, MCP-treated fruit stored in CA did not ripen during the warm room tests after 3, 6 or 9 months storage. After the 9 month test, firmness of MCP treated fruit stored in CA was 10-12 lbs.

A2. MCP treatment delay. MCP treatment (0.1 or 0.8 ppm) of 'd'Anjou' pears was delayed up to 4 weeks after harvest. During the delay, fruit were held in air at 32 ºF. After MCP treatment, fruit were stored at 32 ºF in air or CA (1.5% O_2 , 0.5% CO_2) for up to 9 months, and 7 days at 68 ºF after removal from storage. Fruit quality differences due to treatment delay after harvest for titratable acidity and color were detected after 3 months and for firmness and decay after 6 and 9 months. Superficial scald developed after 6 and 9 months, and treatment differences were due to MCP

concentration as well as treatment delay. Delaying MCP treatment at 0.1 ppm for 2 weeks or longer reduced scald development compared to untreated fruit, however some of these fruit developed scald. Fruit treated at harvest with 0.1 ppm did not scald, and 0.8 ppm MCP treatment up to 4 weeks after harvest completely prevented scald. However, fruit treated at 0.8 ppm and stored in CA remained firm through 9 months plus 7 days at 68 ºF. After 9 months, the incidence of decay also increased with treatment delay.

A3. MCP dose response and storage environment. A more in-depth study of MCP dose and storage conditions was conducted with 'd'Anjou' pears. Fruit were treated at harvest with 0, 0.1, 0.2, 0.4, or 0.8 ppm MCP for 12 h at 32 ºF, then stored at 32 ºF in air or CA (1.5% O_2, 0.5% CO_2). No consistent MCP dose related trends were evident through 9 months storage plus 7 d at 68 ºF.

A4. 'd'Anjou' pears previously stored at 32 ºF in air (2, 3 or 4 months) or CA (1.5% O_2, 0.5% CO_2 , 4 or 8 months) were treated with 1 or 10 ppm MCP 1 day after removal from storage. Fruit were then held at 68 ºF for up to 14 days. Both MCP concentrations slowed ripening of fruit stored in air. After 2 months in air, MCP treatment slowed degreening, softening and development of decay. MCP treatment after 3 or 4 months in air prevented development of internal breakdown, slowed progression of decay but fruit softening was not prevented. No superficial scald developed on any air-stored fruit.

MCP treatment after 4 months CA storage reduced the rates of degreening and softening as well as loss of titratable acidity. Softening progressed into an acceptable range. MCP treatment after 8 months was much less effective.

'd'Anjou' 2001-2002 (partial results)

A1. Storage temperature. 'd'Anjou' fruit were treated at harvest with 0, 0.1 or 0.5 ppm MCP, then stored in air at 32, 41 or 50 ºF. Fruit were removed to 68 ºF for 7 days prior to analysis. MCP treatment at either concentration prevented ripening and development of disorders for all fruit stored after 1 month and for fruit stored at 32 or 41 ºF for 3 months. MCP treated fruit stored at 50 ºF for 3 months ripened after return to 68 ºF.

PROCEDURES: 2002-2003

1. Optimization of treatment and post-storage conditions. Factors to be evaluated include MCP concentration, delay after harvest, combination treatments with fungicides, and duration of post-storage holding necessary for ripening to occur.

2. Response of treated fruit stored in RA or CA. Storage temperature and CA gas composition will be evaluated.

3. Efficacy of treatments of partially ripe fruit based on fruit firmness will be conducted using fruit from multiple harvests and after various storage durations in RA and CA.

4. Physiological indicators of fruit development (respiration, ethylene production and ethylene sensitivity) will be evaluated as predictors of ripening potential and MCP response.

5. MCP effects on metabolism of pigments and other phytoactive compounds will be performed.

BUDGET
Management of Pear Fruit Ripening with 1-Methylcyclopropene (MCP)
James Mattheis
Project duration: 2000-2003
Current year: 2002
Original budget request:

Year	Year 1 (2000)	Year 2 (2001)	Year 3 (2002
Total	21, 016	26, 275	26,546

Current year breakdown:

Item	Year 1 (2000)	Year 2 (2001)	**Year 3 (2002)**
Salary	14,012	23,275	**18,728**
Supplies	2,800	2,800	**2,200**
Benefits	4,204		**5,518**
Travel		200	
Total	21,016	26,275	26,546

[1] GS-9 biological science technician, 0.5 FTE

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CONTINUING REPORT

TITLE: Red d'Anjou Failure

PROJECT LEADER: Eugene A. Mielke, OSU, MCAREC

COOPERATORS: Robert Spotts, OSU, MCAREC
Joe Postman, USDA Germplasm Repository, Corvallis

FUNDING HISTORY:
Year initiated: 1998
Funding in 2001-2002: $16,531

SIGNIFICANT FINDINGS:

Crop load reduction resulted in an increase in the percentage of Columbia Red d'Anjou fruit rated as US #1. This increase was due primarily to a greater percentage of red color in the fruit. As the level of crop removal increased, there was a shift to larger fruit sizes. Average fruit size increased with crop removal, resulting in an increase in the per ton crop value. With the increase in crop value, the 25% reduction in total fruit, still resulted in an increase in the per acre returns.

Reduction in the rate of water application resulted in a significant increase in the percentage of grade "US # 1" fruit. Average fruit size was reduced at the lowest irrigation level. The per ton crop value was reduced at the greatest level of water reduction. Overall production was increased with a slight reduction in water application and total crop value was increased with slightly reduced water applications.

Changes in both cropping and irrigation levels affect the production, size, and quality of Columbia Red d'Anjou pears. Reducing the cropping level reduces stress observed in the tree as measured by the presence of earlier fall red coloration. The tree begins to "recover" within a year of reduced cropping as measured by the later onset of red fall coloration. Excessive irrigation keeps the tree more vigorous and reduces cropping, both of which reduce tree stress. Columbia Red d'Anjou trees have a significantly smaller root system, and more of the tree's carbohydrates appear to have been partitioned into the fruit and top at the expense of the root as evidenced by less structural wood in the top of the tree and an even smaller structural root system. Thinning the trees to reduce crop load is not an economically viable way to reduce tree stress. Future research will explore methods for improving root growth and management techniques to reduce stress.

OBJECTIVES:

1. Determine the effect of crop load in causing the collapse of Columbia Red d'Anjou trees or in the severity of the collapse.

2. Determine the effect of water stress in causing the collapse or in the severity of the collapse.

3. Determine if own-root trees can prevent the development of Columbia Red d'Anjou failure by the elimination of the propagation union or any incompatibility between the scion and rootstock.

4. Determine if combination green/red trees can alleviate the condition or prevent its development.

PROCEDURES:

Objective 1: Determine the effect of crop load in causing the collapse of Columbia Red d'Anjou trees or in the severity of the collapse.

Heavy bearing young trees were thinned to leave 0, 25, 50, or 75 % of the crop, with a non-thinned control. The experimental design was a randomized complete block design with four, six-tree replicates. At harvest the crop was collected, passed across the experimental packing line at MCAREC to determine the effect of the treatments on color, size and grade. The trees were annually rated at the end of the growing season for stress as measured by the time of appearance of red fall coloration.

Objective 2: Determine the effect of water stress in causing the collapse or in the severity of the collapse.

Trees were subjected to a 25, 37, and 48 percent water reduction. Cropping level, fruit size, and color were determined at harvest. Fall root samples were collected, and analyzed for carbohydrate content. At harvest the crop was collected, passed across the experimental packing line at MCAREC to determine the effect of the treatments on color, size and grade.

Objective 3: Determine if own-root trees can prevent the development of Columbia Red d'Anjou failure by the elimination of the propagation union or any incompatibility between the scion and rootstock.

Once own-rooted red d'Anjou trees are available, they will be planted in at least three locations where collapse symptoms have been noted. The trees will be followed for the development of collapse.

Objective 4: Determine if combination green/red trees can alleviate the condition or prevent its development.

Red d'Anjou trees are being developed with a permanent lower whorl of either green Bartlett or green d'Anjou. The effect on tree growth will be measured and its impact on the development of the disorder.

RESULTS AND DISCUSSION:

Crop Reduction: Overall crop load in 2001 was approximately 2/3s of that in 2000. Crop reduction did result in changes in the percentage of red color in the fruit. As the level of cropping was reduced, there was a shift of fruit from the greenest to reddest classes. The color classes coincided with fruit grade. As cropping level was reduced, there was a greater shift from "unclassified" to "US #1" fruit. These results are similar to those observed in 2000. A reduction in cropping level also resulted in a shift in fruit from sizes 70 and smaller to sizes 60 and larger. Again the shift to larger sizes was greater with a greater reduction in the cropping level. This resulted in 21% increase in average fruit size at the 25% cropping level. The changes in both grade and size affected the value of the crop. Crop value rose from $608 per ton at the 100% cropping level to $753 per ton at the 25% cropping level. Yield was significantly reduced with crop removal; however, the increase in fruit size partly offset the reduction in fruit numbers. The increase in crop value at the 75% cropping level offset the reduction in yield. These data are also similar to 2000.

Trees were evaluated for the presence of stress by the time when early red foliage appeared in the trees. The earlier the red foliage appeared, the more stress the trees were under. Trees that

retained green leaves late into the season were assumed to be under less stress. Stress was evaluated on a 1 – 10 scale, where 1 = extremely weak/stressed, 5 = normal growth, 10 = excessively vigorous/low stress. Reducing the cropping level significantly improved the stress ranking of the trees in 2000. The decrease in stress (as indicated by a higher number) was significant when the crop level was reduced to 50% or less. The lower overall crop in 2001 reduced the stress on all treatments and there was little difference in the treatments. The difference in stress levels between years is more definitive than the actual levels. Between 1999 and 2000 (a heavy cropping year), cropping levels of 75% and 100% actually increased tree stress (as indicated by the larger negative value), while reducing the cropping level to 50% or less reduced tree stress. Due to the lower crop level in 2001 all treatments exhibited less stress. The trees at the highest cropping levels exhibited the greatest stress reduction.

Irrigation Reduction: As with changes in cropping level, changes in irrigation level resulted in changes in fruit color. A significant change occurred in a shift in fruit from the greener to redder classification, which resulted in a shift in grade. Reducing the irrigation level increased production. Decreasing the irrigation level to 52% resulted in a reduction in average fruit size due to the significantly larger crop load. These results are similar to those seen in 2000. This resulted in a 15% reduction in the per ton crop value at the 52% irrigation level for the second year in a row. There was a 19 percent increase in per ton crop value when irrigation was reduced to the 75% level. The increased per ton valuation coupled with the increased yield at the 75% irrigation level, significantly increased grower returns. Due to overall reduction in production in the district by approximately 2/3s, all trees exhibited excessive vigor.

Own-Rooted Trees: It has still not been possible to develop roots on Columbia Red d'Anjou cuttings. The test has therefore not been carried out. If, and when, own-rooted material becomes available it will be evaluated, but at this time it is not a high enough priority to attempt to tackle the propagation problem.

Combination Red-Green Trees: The combination trees are young and have not experienced a major cropping stress. The presence or absence of a red top did not affect tree height or spread, or canopy volume.

Root Development: A group of 10-year-old green and Columbia Red d'Anjou trees on OHxF 40 rootstocks were selected for root extraction. The green- and red-topped trees had similar yields; however, the green-topped trees had more fruit and a significantly smaller fruit size. Trees with green tops had significantly larger trunk cross sectional areas (TCSA) and top weights as compared to trees with red tops. While 11 green- and 12 red- topped trees were available, only 5 green- and 4 red-topped trees were actually extracted by washing the soil away from the roots down to a depth of 4 feet. Class averages for the extracted trees were almost identical with the larger population. The root weight for the red-topped trees was only half of that of the green-topped counterparts. There were also fewer roots of a smaller diameter that extended below four feet. Reduced structural components of the tree coupled with similar production indicate that red-topped trees partition more of the carbohydrates to the fruit. If we examine the relationship of the structural components we find that there is a smaller ration of both top and root weight relative to the TCSA. Additionally, the ratio of top to roots indicates that the red-topped tree preferentially partitions carbohydrates to the fruit and top portions of the tree at the expense of the roots.

CONCLUSIONS:

Changes in both cropping and irrigation levels affect the production, size, and quality of Columbia Red d'Anjou pears. Reducing the cropping level reduces stress in the tree, and the tree begins to "recover" from the stressed condition within a year of reduced cropping. Excessive

irrigation keeps the tree more vigorous and reduces cropping, both of which reduce tree stress. Columbia Red d'Anjou trees have a significantly smaller root system, and more of the tree's carbohydrates are partitioned to the fruit and top at the expense of the root. Thinning the trees to reduce crop load is not an economically viable way to reduce tree stress. Future research will explore methods for improving root growth and management techniques to reduce stress.

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CONTINUING PROJECT REPORT

Title: Evaluation of Harvest Maturity and Quality Aspect of Pear Cultivars in the Northwest

Project Leader: Clark F. Seavert

Cooperators: Paul M. Chen, Eugene Mielke, Steve Castagnoli, and David Burkhart

Funding History:
Year Initiated: 2000
Funding in 2001-2002: $18,641
Funding requested for 2002-2003: $23,809

SIGNIFICANT FINDINGS:

In the year 2000 a new pear variety trial was established at the MCAREC consisting of 1.1 acres. Two distinct phases are designed to evaluate the pear cultivars. The first phase evaluates pear cultivars for their adaptability to the PNW. Cultivars deemed to meet criteria set forth by the HRGSA Research Committee are then evaluated in Phase 2 for long-term storage characteristics.

Objective 1 Establish new and maintain current pear varieties

To minimize the stress to these trees that were transplanted in 2000, they were pruned heavily in 2000 and thinned heavily in spring 2001. First and full bloom data were collected on 21 varieties. The bloom span for the varieties ran from 4/8/01 for first bloom to 4/26/01 for full bloom.

Objective 2 To maintain a pear rootstock nursery

Some of these rootstocks were used in fall 2001 to graft varieties from phase one to increase the number of trees for each variety to 5 trees.

Objective 3 To establish and maintain two varieties of pear - 'Taylor's Gold' and 'Concord'.

The trees were planted, pruned and trained.

Objective 4 To identify the optimum harvest maturity date and the storage life of 'Lariza' pear cultivar.

In the 2001-2002 season, the results were basically the same as the findings in 2000-2001. We suggest that the optimum maturity of 'Lariza' pears is when the flesh firmness (FF) is decreased to between 12 lb and 10.5 lb and the optimum storage life of this cultivar is around 3 months in air at –1C.

Objective 5 To identify the optimum harvest maturity and storage life of 'Moore Red' pear cultivar.

In the 2001-2002 season, the results were basically the same as the findings in 2000-2001. We suggest that the optimum maturity of 'Moore Red' pears is when the flesh firmness (FF) is decreased to between 16 lb and 14 lb and the optimum storage life of this cultivar is around 3 months in air at –1C.

OBJECTIVES:

Phase 1

1. To establish new and maintain current pear varieties.
2. To establish and maintain pear rootstock nursery.

Phase 2.

3. To establish and maintain two varieties of pear – Taylor's Gold and Concorde.
4. To identify the optimum harvest maturity and storage life of 'Lariza' pear cultivar.
5. To identify the optimum harvest maturity and storage life of 'Moore Red' pear cultivar

PROCEDURES:

Objective 1. Establishing new and maintaining current pear varieties.

a) orchard maintenance: pruning; training; planting new varieties; weeding;budding and grafting;
b) data collection: bloom dates: first and full; bloom count and fruit set; harvest samples: up to 4 intervals during harvest season; pressures and soluble solids
c) Fruit Storage: sorting and packing; labeling; evaluating ripening, tasting, and storage disorders
d) Record keeping: mapping varieties for visitors; identifying variety of tree with tags; harvest, bloom and tabular data
e) Reporting: display fruit at Washington State Horticultural Society meeting in December; display and show variety trial at station tours and annual field day; present current information with pictures on MCAREC web site (osu.edu/dept/mcarec)

Objective 2. Establish and maintain pear rootstock nursery.

a) 160 OHxF 97 rootstock will be planted in 2001 and maintained for grafting varieties that are difficult to purchase on appropriate rootstock

Objective 3. To establish and maintain two varieties of pear – Taylor's Gold and Concorde.

a) In the spring of 2001, 80 trees (40 Taylor's Gold and 40 Concorde) will be planted in Phase 2.

Objective 4. To identify the optimum harvest maturity and storage life of 'Lariza' pear cultivar.

Procedures will be repeated as proposed in 2000-2001 season in order to verify the findings of postharvest behaviors of 'Lariza' pears harvested at different maturities as reported in 2000-2001 season.

a) Harvest 12 boxes 'Lariza' fruit from the orchard at each harvest interval. Sample 10 fruit at each harvest for FF, SSC.
b) Transfer fruit to 4/5 volume bushel boxes with polyliners and store at 30°F (±0.5°F).
c) After 2, 4, and 6 months of cold storage at 30°F, transfer three boxes from each harvest into a ripening room at 68°F.
d) On day 1, 5 and 7 of ripening, use 10 fruit per box for FF, EJ, TA and SS measurement.
e) On day 5 and 7 of ripening, assess the incidences of storage disorders including senescent scald and internal browning
f) On day 5 and 7 of ripening the dessert quality of ripened fruit including flesh texture and flavor will be rated on a nine point hedonic scale with 9=buttery and juicy texture and flavorful taste and 1=mealy, coarse and dry texture and off flavor.

Objective 5. To identify the optimum harvest maturity and storage life of 'Moore Red' pear cultivar.

Procedures will also repeat the same as proposed in 2000-2001 season in order to verify the findings of postharvest behaviors of 'Moore Red' pears harvested at different maturities as reported in 2000-2001 season.

a) Harvest 12 boxes 'Moore Red' fruit from the orchard at each harvest interval. Sample 10 fruit at each harvest for FF, SSC.
b) Transfer fruit to 4/5 volume bushel boxes with polyliners and store at 30°F (±0.5°F).

c) After 2, 4, and 6 months of cold storage at 30°F, transfer three boxes from each harvest into a ripening room at 68°F.
d) On day 1, 5 and 7 of ripening, use 10 fruit per box for FF, EJ, TA and SS measurement.
e) On day 5 and 7 of ripening, assess the incidences of storage disorders including senescent scald and internal browning.
f) On day 5 and 7 of ripening the dessert quality of ripened fruit including flesh texture and flavor will be rated on a nine point hedonic scale with 9=buttery and juicy texture and flavorful taste and 1=mealy, coarse and dry texture and off flavor.

RESULTS AND DISCUSSION:

Objective 1 Establish new and maintain current pear varieties

Twenty-one varieties deemed to have met the criteria for evaluation in the new variety trial and were moved in May 2000 from the old pear collection block. Trees in Phase I were planted, pruned, trained, weeded and some varieties were budded or grafted. In order to minimize the stress to the trees that were transplanted in 2000, they were pruned heavily in 2000 and thinned heavily in spring 2001. As a result there is a limited amount of harvest data from 2001, consisting of first and full bloom dates, and flesh firmness pressures from the harvest sampling intervals. Potential yield for each variety were assessed in early August, and sampling intervals were planned to collect 6 fruit for pressures, and a small sample for cold storage. Limited quantities of fruit were available for display at the Washington State Horticultural Society meeting in December.

One new variety was added to phase I. It is 'P15-157', a WilliamsxConference cross from the pear-breeding program at East Malling, U.K.

First and full bloom data was collected on 21 varieties. The bloom span for the varieties ran from 4/8/01 for first bloom to 4/26/01 for full bloom (refer to Table 1).

Each tree in phase I is individually tagged with variety, rootstock, row and tree number on it.

Table 1. Flowering range (first to full bloom) for phase I pear cultivars in 2001. Date of first bloom for Bartlett was 4/15 and full bloom was 4/22. Bartlett bloom is included in this table as a reference.

	April																		
Cultivar	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Tosca	X	X	X	X	X	X	X	X	X										
Potomac						X	X	X	X	X	X	X	X						
US76128-009								X	X	X	X	X	X	X					
Bartlett								**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Chateau Royal TM								X	X	X	X	X	X	X	X				
US71655-014									X	X	X	X	X	X	X	X			
INRA #2829									X	X	X	X	X	X	X	X			
Rosemarie									X	X	X	X	X	X					
Lariza (Banjo)										X	X	X	X	X	X	X	X		
INRA #2026										X	X	X	X	X	X	X			
INRA #2661										X	X	X	X	X	X	X	X		
Moore Red Pear										X	X	X	X	X	X	X			
US66131-021										X	X	X	X	X	X	X			
US66170-047										X	X	X	X	X	X	X			
US67218-083											X	X	X	X	X	X	X		
US66125-035											X	X	X	X	X	X	X		
US71660-045											X	X	X	X	X	X	X		
US76115-010											X	X	X	X	X	X	X		
Madeira											X	X	X	X	X	X	X		
Cinnamon												X	X	X	X				
US78304-057												X	X	X	X	X	X		
Taylor's Gold																	X	X	X

Objective 2 To maintain a pear rootstock nursery
A pear rootstock nursery was planted and maintained throughout the season, consisting of 160 OhxF 97 rootstocks for grafting varieties that are difficult to purchase on appropriate rootstock. Some of these rootstocks were used in fall 2001 to graft varieties from phase one to increase the

Objective 3 To establish and maintain two varieties of pear - 'Taylor's Gold' and 'Concord'.
Taylor's Gold on OhxF87 and Concord on OhxF 97 were planted in Phase Two. Row cover, irrigation, and support system was installed. The trees were pruned and trained.

Objective 4. To identify the optimum harvest maturity and storage life of 'Lariza' pear cultivar.
The most distinguishable indicators for evaluating the ripening activities of pear fruit in this project are flesh firmness (FF) and extractable juice (EJ) (Table 2-1). Normal ripening of 'Lariza' pears for Harvest 1 required up to 7 days at 20C to reach the proper eating quality if harvested fruit had been stored at –1C in air for 2 months or longer. Decrease of flesh firmness was steady from day 1 to day 7, yet reduction of EJ was not significant during ripening. (The reduction of EJ of ripened fruit indicates an increase in juice-binding capacity of pulp tissue which results in juicy and buttery texture). Texture and flavor in the 'Lariza' for Harvest 1 was better on day 7 indicating this harvest required 7 days at 20C or longer even though FF on day 5 and 7 of ripening was similar and was around 2.47lb to 2.31lb (Table 2-1). There were no differences in TA content before and after ripening 'Lariza" for 7 days. SSC in 'Lariza' pears did not change during 7 days of ripening at 20C (Table 2-1).

Table 2-1.

Differences in flesh firmness (FF) (lb), extractable juice (EJ) (ml/100 g F.W.), titratable acidity (TA) (meq/100 ml), soluble solids concentration (SSC) (%), texture quality (score 1-9), and flavor quality (score 1-9) of 'Lariza' pears on day 1 (Unripened) and day 5 (Ripened), and day 7 (Ripened) of ripenng at 20ºC. 'Lariza' fruit were harvested on August 21 (Harvest 1). Harvested fruit were stored in air at -1ºC for 4 months. (There was no fruit left to sample from subsequent harvests.)

Harvest	Days at 20C	FF	EJ	TA	SSC	Texture	Flavor
1	1	5.56±.1.02	64.00±3.46	3.10±.41	12.47±.93	.	·
	5	2.47±.06	64.33±.58	3.25±.06	12.10±.66	6	5
	7	2.31±.17	63.67±1.53	3.19±.04	12.43±.81	7	6

Objective 5. To identify the optimum harvest maturity and storage life of 'Moore Red' pear cultivar.
Normal ripening of 'Moore Red' pears usually required 5 days at 20C to reach the proper eating quality if harvested fruit had been stored at –1C in air for 4 months (Table 2-2). Decrease of FF was also associated with a distinct reduction of EJ in the 'Moore' Red' pears during ripening. TA in Harvest 1 fruit were slightly higher that those in Harvest 2 fruit while SSC in Harvest 1 fruit were slightly lower than those in Harvest 2 fruit (Table 2-2). Flesh firmness, and soluble solids concentration on dates of harvest are displayed in Table 2-2.

Texture quality of ripened 'Moore Red' pears was between 6 and 4 for both harvests indicating that this fruit from harvest 1 developed more buttery and juicy texture. EJ was significantly reduced between day 1 and day 7 in harvest 1, whereas reduction of EJ in harvest 2 could only be

recorded through day 5, since day 7 fruit had deteriorated (Table 2-2). Flavor quality was scored between 6 and 4 for Harvest 1 and 2 respectively (Table 2-2). The results indicated that 'Moore Red' pears harvested at the maturity no later than Harvest 1 is necessary in order to develop the desirable texture as well as flavor qualities upon ripening during the marketing season.

Table 2-2
Differences in flesh firmness (FF) (lb), extractable juice (EJ) (ml/100 g F.W.), titratable acidity (TA) (meq/100 ml), soluble solids concentration (SSC) (%), texture quality (score 1-9), and flavor quality (score 1-9) of 'Moore Red' pears on day 1 (Unripened) and day 5 (Ripened), and day 7 (Ripened) of ripenng at 20ºC. 'Moore Red" fruit were harvested on August 15 (Harvest 1), and August 22 (Harvest 2). Harvest 2 day 7 fruit deteriorated to the point of being unable to sample. Harvested fruit were stored in air at -1ºC for 4 months.

Harvest	Days at 20C	FF	EJ	TA	SSC	Texture	Flavor
1	1	12.21±.45	69.00±2.0	3.75±.36	11.43±.06	.	.
	5	3.49±.17	65.67±.58	3.96±.17	11.43±.06	6	6
	7	2.23±.11	63.67±.58	4.38±.15	11.23±.25	2	2
2	1	10.40±.48	69.33±1.15	3.56±.22	12.27±.23	.	.
	5	3.88±.29	66.33±.58	3.33±.15	11.93±.12	4	4

CONCLUSIONS:

Pear cultivars in Phase 1 did not yield much in 2001 but current fruit set indicates a larger harvest for evaluation in 2001. It is concluded that the storage life of 'Lariza' pears is no longer than 3 months in air at-1C if fruits are harvested with FF of 12 lbs or lower. However, the storage life of this cultivar could be extended to 4 months in air at –1C if the fruits are harvested with FF of 14 lbs. Although early harvested fruits have longer storage life as compared to normal and late harvested fruits, they lack flavor upon ripening regardless of the length of storage. 'Moore Red' fruit should not be harvested too early with FF higher than 16 lbs since they lack flavor upon ripening.

PROPOSAL FOR 2002

SIGNIFICANT FINDINGS:

Objective 1 Establish new and maintain current pear varieties

In the year 2000 a new pear variety trial was established at the MCAREC consisting of 1.1 acres. The variety trial was split into Phase 1 and 2. Varieties meeting the criteria set forth by the HRGSA Variety Sub-committee are further evaluated in Phase 2 for more detailed data on storage characteristics.

In Phase I, .6 acres are available for 200 trees - 40 varieties with five trees of each variety. In Phase II, .5 acres are available for another 200 trees - five varieties with 40 trees of each variety. Twenty-one varieties deemed to have met the criteria for evaluation in the new variety trial and were moved in May 2000 from the old pear collection block. Trees in Phase I were planted, pruned, trained, weeded and some varieties were budded or grafted. In order to minimize the stress to the trees that were transplanted in 2000, they were also pruned heavily in 2000 and thinned heavily in spring 2001. As a result there is a limited amount of harvest data from 2001, consisting of first and full bloom dates, and flesh firmness pressures from the harvest sampling intervals. Potential yield for

each variety were assessed in early August, and sampling intervals were planned to collect 6 fruit for pressures, and a small sample for cold storage. Limited quantities of fruit were available for display at the Washington State Horticultural Society meeting in December.

One new variety was added to phase I. It is 'P15-157', a WilliamsxConference cross from the pear-breeding program at East Malling, U.K.

First and full bloom data was collected on 21 varieties. The bloom span for the varieties ran from 4/8/01 for first bloom to 4/26/01 for full bloom.

Each tree in phase I is individually tagged with variety, rootstock, row and tree number.

Objective 2 To maintain a pear rootstock nursery

A pear rootstock nursery was planted and maintained throughout the season, consisting of 160 OhxF 97 rootstocks for grafting varieties that are difficult to purchase on appropriate rootstock. Some of these rootstocks were used in fall 2001 to graft varieties from phase one to increase the number of trees for each variety to 5 trees.

Objective 3 To establish and maintain two varieties of pear - 'Taylor's Gold' and 'Concord'.

Taylor's Gold on OhxF87 and Concord on OhxF 97 were planted in Phase Two. Row cover, irrigation, and a support system was installed. The trees were pruned and trained.

Objective 4 To identify the optimum harvest maturity date and the storage life of 'Lariza' pear cultivar.

This project was initiated in 2000-2001 season. 'Lariza' pear cultivar was harvested twice at weekly intervals over a 16-day period beginning September 1, 2001. Harvested fruit at each harvest interval were subsequently referred to as Harvest 1 and Harvest 2, respectively. Harvested fruit were stored in 4/5 volume bushel boxes at –1C. Harvested fruit stored for 4 and 6 months were all deteriorated upon ripening regardless of harvest intervals excepted Harvest 1 were considered as acceptable. It is concluded that the storage life of 'Lariza' pears is estimated no longer than 3 months in air at-1C if fruits are harvested with FF of 12 lbs or lower. However, the storage life of this cultivar could be extended to 4 months in air at –1C if the fruits are harvested with FF of 14 lbs. Although early harvested fruits have longer storage life as compared to normal and late harvested fruits, they lack flavor upon ripening regardless of the length of storage.

In the 2001-2002 season, the results were basically the same as the findings in 2000-2001. We suggest that the optimum maturity of 'Lariza' pears is when the flesh firmness (FF) is decreased to between 12 lb and 10.5 lb and the optimum storage life of this cultivar is around 3 months in air at –1C. Fruit should not be harvested too early with FF higher than 13 lbs since they lack flavor upon ripening as well as they are small in size. Average fruit weight for fruit harvested both years was .4lbs.

Objective 5 To identify the optimum harvest maturity and storage life of 'Moore Red' pear cultivar.

This project was initiated in 2000-2001 season. 'Moore Red ' pear cultivar was harvested at weekly intervals over a 7-day period beginning August 15, 2000. Harvested fruit at each harvested interval were subsequently referred to as Harvest 1 and Harvest 2, respectively. Harvested fruit were stored in 4/5 volume bushel boxes at –1C. After four months of storage, 'Moore Red' pears deteriorated upon ripening. Harvest 1 fruit showed the highest reduction in EJ, but not a significant enough drop to indicate buttery and juicy texture. Flavor of harvest 1 was rated higher than harvest 2, but again the hedonic ratings indicated a soft texture and poor flavor.

In the 2001-2002 season, the results were basically the same as the findings in 2000-2001. We suggest that the optimum maturity of 'Moore Red' pears is when the flesh firmness (FF) is decreased to between 16 lb and 14 lb and the optimum storage life of this cultivar is around 3 months

in air at –1C. Fruit should not be harvested too early with FF higher than 16 lbs since they lack flavor upon ripening.

OBJECTIVES:

Phase 1

6. To establish new and maintain current pear varieties.
7. To maintain pear rootstock nursery.

Phase II

8. To maintain phase II plantings of 'Taylor's Gold and Concord'.
9. To investigate the storage life of commercially harvested 'Moore Red' pears and compare those characteristics to the 'Starkrimson' pear to evaluate storage differences.

PROCEDURES:

Objectives 1 and 2, phase I will repeat the same procedures as proposed in 2000-2001 season.

A) Orchard maintenance: i) pruning, ii) training, iii) planting new varieties, iv) weeding, v) budding and grafting.
B) Data collection: i) bloom dates: first and full, ii) bloom count and fruit set, iii) harvest samples: up to 4 intervals during harvest season, iv) pressures at harvest.
C) Fruit Storage: i) sorting and packing, ii) labeling, iii) evaluating ripening, tasting, and storage disorders.
D) Record keeping: i) mapping varieties for visitors, ii) identifying variety of tree with tags iii) harvest, bloom and tabular data
E) Reporting: i) display fruit at Washington State Horticultural Society meeting, ii) display and show variety trial at station tours and annual field day, iii) present current information with pictures on MCAREC web site (osu.edu/dept/mcarec)

Objective 3, phase 2.

A) Maintain current varieties established in phase II ('Taylor's Gold and Concord'): i) pruning, ii) training, iii) weeding
B) Data collection of phase II: i) bloom count and fruit set, ii) TCSA cm^2, iii) canopy height and spread, iv) individual tree yield
C) To identify the optimum harvest maturity and storage life of phase II varieties:
   i. Harvest 12 boxes of fruit from each variety with a FF of 16-14 lbs. Sample 10 fruit at harvest for FF, SSC.
   ii. Transfer fruit to 4/5 volume bushel boxes with polyliners and store at 30°F (±0.5°F).
   iii. After 2, months, 4 months, and every two weeks thereafter of cold storage at 30°F, transfer three boxes into a ripening room at 68°F.
   iv. On day 1, 5 and 7 of ripening, use 10 fruit per box for FF, EJ, TA and SS measurement.
   v. On day 5 and 7 of ripening, assess the incidences of storage disorders including senescent scald and internal browning.
   vi. On day 5 and 7 of ripening the dessert quality of ripened fruit including flesh texture and flavor will be rated on a nine point hedonic scale with 9=buttery and juicy texture and flavorful taste and 1=mealy, coarse and dry texture and off flavor.

Objective 4, phase 2. To investigate the storage life of commercially harvested 'Moore Red' pears and compare those characteristics to the 'Starkrimson' pear to evaluate storage differences.

This objective will also repeat the same procedures as proposed in 2000-2001 season in order to

verify the findings of post harvest behaviors of 'Moore Red' pears, but will use one harvest with the flesh firmness between 16 and 14lbs.

i. Harvest 12 boxes of 'Moore Red ' fruit from the orchard with a FF of 16-14 lbs. Sample 10 fruit at harvest for FF, SSC.
ii. Transfer fruit to 4/5 volume bushel boxes with polyliners and store at 30°F (±0.5°F).
iii. After 2, months, 4 months, and every two weeks thereafter of cold storage at 30°F, transfer three boxes into a ripening room at 68°F.
iv. On day 1, 5 and 7 of ripening, use 10 fruit per box for FF, EJ, TA and SS measurement.
v. On day 5 and 7 of ripening, assess the incidences of storage disorders including senescent scald and internal browning
vi. On day 5 and 7 of ripening the dessert quality of ripened fruit including flesh texture and flavor will be rated on a nine point hedonic scale with 9=buttery and juicy texture and flavorful taste and 1=mealy, coarse and dry texture and off flavor.
Harvest 12 boxes 'Starkrimson' fruit from the orchard with a FF of 16-14 lbs. Sample 10 fruit at harvest for FF, SSC.
vii. Harvest 12 boxes of 'Starkrimson' fruit from the orchard with a FF of 16-14 lbs. Sample 10 fruit at harvest for FF, SSC.
viii. Transfer fruit to 4/5 volume bushel boxes with polyliners and store at 30°F (±0.5°F).
ix. After 2, months, 4 months, and every two weeks thereafter of cold storage at 30°F, transfer three boxes into a ripening room at 68°F.
x. On day 1, 5 and 7 of ripening, use 10 fruit per box for FF, EJ, TA and SS measurement.
xi. On day 5 and 7 of ripening, assess the incidences of storage disorders including senescent scald and internal browning
xii. On day 5 and 7 of ripening the dessert quality of ripened fruit including flesh texture and flavor will be rated on a nine point hedonic scale with 9=buttery and juicy texture and flavorful taste and 1=mealy, coarse and dry texture and off flavor.

ESTIMATED DURATION: 10 years

BUDGET
Title: Evaluation of Harvest Maturity and Quality Aspect of Pear Cultivars in the Northwest
Project Leader: Clark F. Seavert

Item	Amount Requested
Salaries and Wages:	
Technician	$14,404
Temp	844
OPE - Technician - (.53 actual)	6,893
Temp	68
Service and Supplies	1,000
Travel - Technician (WSHA)	400
Travel - Technician (Fruit Tester Assoc. Tour)	200
Grand Total	$23,809